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Original Articles—

ORIGINAL ARTICLES

STUDIES ON INDIAN CUCURBITACEAE

With Special Remarks on Distribution and Uses of Economic Species

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(Received for publication on 26 March 1945)

(With Plates I-XII and four text-figures)

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INTRODUCTION

INDIAN Cucurbitaceae furnish an interesting histological study owing first to the presence of distinct bicollateral nature of bundles in the stem and to the presence of anomalous anatomical characters in some of the genera, secondly to the special contrivances of depositing calcium carbonate and calcium oxalate, during the process of metabolism, in the shape of cystoliths and crystals respectively in the epidermal cells of the leaves. Morphologically it is interesting for the presence of extrafloral nectaries in the vegetative organs especially on the leaf blade and the petiole and also for the mechanism in the construction of the flower and the tendril which is still a debatable problem. Economically Cucurbitaceae play an important role in the supply of a good many of our common vegetables and also in the supply of a substantial number of indigenous drugs obtainable from genera like *Trichosanthes, Lagenaria, Luffa, Benincasa, Momordica, Cucumis, Citrullus, Coccinia* (*Cephalandra*), *Cucurbita, Bryonopsis* (*Bryonia*), *Mukia*, etc.

Some of the species of Cucurbitaceae are cultivated and some are found in a wild state, throughout India. In the alpine zones of the Himalayas, above 9,000 ft., cucurbitaceous plants generally cease to exist.

This important family is principally confined to the tropics. In India both the climbing and trailing species are met with in great abundance. The climbing Cucurbits often attain so great a size that they completely cover large trees with luxuriant foliage. This well-known family of which some of the species are very extensively cultivated is still far from being well understood. The structure and habits of these plants are so peculiar that it is difficult to find any parallel with which to compare them and learn by analogy their true relations in the vegetable kingdom. The family thus stands almost alone and its species can scarcely be confused with any other except those of the Passifloraceae.

Deferring to their proper place all remarks on the genera and organs from which characters are drawn, the author may observe here that the discrimination of species is extremely difficult as no reliance can be placed on the form of the leaves as affording specific identifying characters. Almost every variation of form, from simple up to much divided leaves, is found in the same species and even occasionally in the same plant. Nearly all the cucurbits are annuals with climbing succulent stems, furnished with tendrils which are supposed as abortive lateral stipules or metamorphosed branches or, according to modern botanical doctrines, transformed leaves, stipules being considered modified leaves. The flowers are usually unisexual, the male and female generally on the same plant (monoecious) or even springing from the same axil ; or rarely they are on different plants (dioecious)

as in *Trichosanthes palmata or T. dioica*, usually the flowers are white, red or yellow. The coloured portion of the flowers is supposed by some botanists to be a petaloid calyx, and the apparent calyx, merely certain external appendages—a view not likely to find many supporters. The stamens in this family are peculiar and present many variations of form. These have sometimes been employed as distinguishing characteristics of the different genera. The fruit like every other part of these singular plants is quite *sui generis* and is in consequence designated by its own name, pepo or peponida, hence Peponiferae—the name given by Bartling and Endlicher to the class. The true pepo as has recently been shown is a tricarpellary fruit but with the carpels inverted, that is with the dorsom of the carpellary leaf in the axis, and the placentiferous margins turned towards the circumference instead of towards the axis as is usual with other fruits. Differences are so great in the construction of this most essential organ that their affinities with other families have still to be determined. In order to facilitate the right understanding of this most difficult and complex family, the following introductory remarks may be useful:

> " Calyx 5-toothed, sometimes obsolete. Petals 5 distinct or more or less united, sometimes scarcely indistinguishable from the calyx, strongly marked with reticulating veins, sometimes fringed, stamens 5, distinct or triadelphous, anthers 2-celled (or rarely 1-celled), usually long, sinuous, rarely ovate, ovary adhering to the tube of the calyx, of 2 or 3 carpels. Carpels inverted that is, having the dorsum in the axis and placentiferous margins in the circumference, hence the fruit 2-3 - celled but with 4 or 6 parietal placentas; ovules solitary or indefinite, imbeded in pulp; style short; stigmas 2 or 3, 2-lobed, very thick, velvety or fringed. Fruit fleshy usually a peponida. Seeds many usually ovate or compressed, enveloped in a juicy or dry and membranous arillus; testa coriaceous, often thick at the margin. Albumen none. Embryo straight; radicle next the hilum; cotyledons foliaceous palmatinerved. Stem succulent; climbing by means of tendrils usually lateral and formed of abortive stipules. Leaves palminerved, alternate; flowers unisexual ".

Geographical distribution

As already stated, the cucurbits are widely distributed throughout the warmer parts of the globe, especially in the tropics. About one hundred genera with about eight hundred species are at present known. Of these, 28 genera comprising about 87 species, occur in the tropical regions of India. About 15 species are cultivated principally for their edible fruits.

The Old World has the greater number of genera but the New World contains a larger number of species. Excluding Cucurbita which is probably not endemic in the Eastern Hemisphere, seven genera are common to the East and the West. This family, though extensively a tropical one and of more frequent occurrence in India than in any other country, has yet a wide distribution over the world, a few being found even as far north as Europe. At the Cape—we learn from Harving's *Genera of South African Plants*—there are species belonging to seven different genera; one species is found in the Norfolk islands, but plants belonging to this family are generally rare in Australia. In equitorial America and Africa they are of more frequent occurrence, but nowhere so abundant as in India and her islands, extending eastwards to China and Japan. Blume enumerates 40 species found in Java alone, which leads one to the inference that the rest of Asia produces at least three or four times as many. Seringe, however, assigns only 70 to Asia, which single fact shows how little the family is known, since more than half of the whole number are from Java.

In the following pages the author has attempted to bring out a complete list of the species of Cucurbitaceae at present found in India and Burma. The area surveyed includes the whole of India comprising Baluchistan and the borders of Afghanistan as the North-West limit, the Himalayas covering the whole eastern, western and central ranges and also the kingdoms of Nepal and Bhutan, as the northern limit and a part of the plateau of Tibet. In the east the area covers the whole of the Indo-Burma frontier penetrating at some places into Yunan, the frontier of China and Burma. In the south, the area covers Ceylon in the Indian ocean and the Andaman and Nicober islands and also the Cocos group in the Bay of Bengal. The Maldives and Laccadives whose flora are akin to the vegetation of Peninsular India have also been embraced. The maps attached herewith will clearly show the area surveyed and the wide range of distribution of wild economic species. The

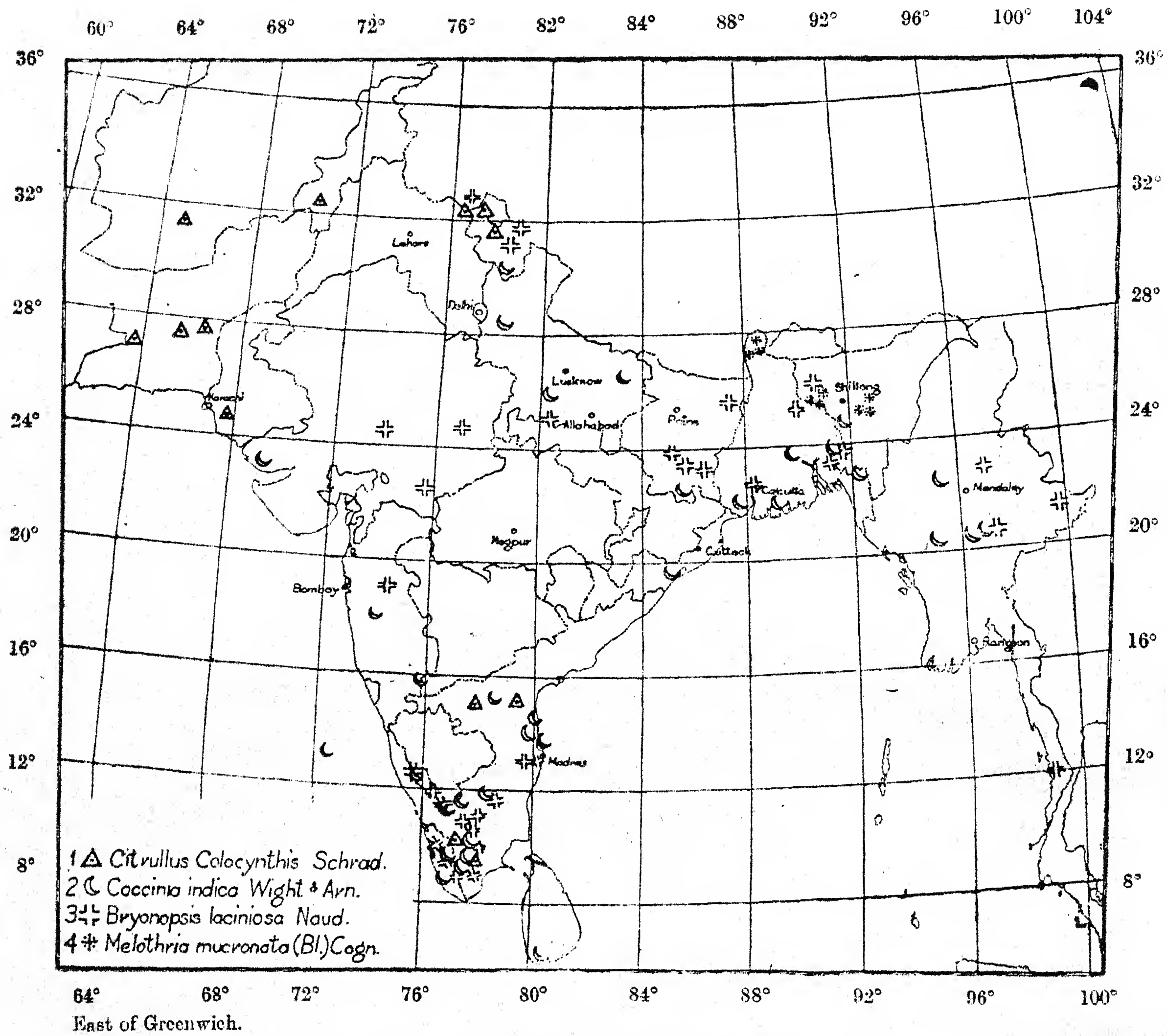

FIG. 1. Distribution of economic cucurbits.

spots of occurrence of these species have been plotted with reference to actual places from where specimens have been collected. The signals indicated in the maps also give in addition an approximate idea of the areas round about which the species in question do occur or are expected to occur. Hooker in his *Flora of British India* has enumerated about 70 species under 29 genera. But a few species have been included along with other new records thus totalling the number of species to 87. The genera *Mukia* and *Zehneria* of *Hooker's Flora of British India* have been reduced to *Melothria*. For the sake of convenience, the measurements of micro structures in the following species have been given in metric system: *Trichosanthes cuspidata* Lam., *T. brevibracteata* Kundu, *T. Perrottetiana* Cogn., *T. villosula* Blume, *T. ovata* Cogn., *T. tricuspidata* Lour., *T. lepiniana* Cogn., *T. anaimalaiensis* Bedd., *T. majuscula* Kundu, *T. khasiana* Kundu, and *Momordica macrophylla* Gage. The genus *Cyclanthera* has been added with one species *Cyclanthera pedata* Schrad.—an American plant which seems to be introduced and naturalized in the North-Western border of the Himalayas. Of the 28 genera occurring in India, 37 species have been recorded as endemic and the rest are non-endemic. Some of these non-endemic species may be traced to have travelled from Europe, a good many from Africa and quite a lot from Malaysia. Table I will explain the comparative relationships of the Indian species with those of the world.

TABLE I

Numerical comparison of the Indian species with those of the world

Genera	Total number of species in the world	Number of endemic species	Number of non-endemic species	Total number of species found in India	Percentage of Indian species in comparison with those of the world
Hodgsonia	1	..	1	1	100
Trichosanthes	44	18	5	23	52·2
Gymnopetalum	6	2	2	3	50
Biswarea	1	1	..	1	100
Lagenaria	1	..	1	1	100
Herpetospermum	1	1	..	1	100
Luffa	6	1	4	5	83·3
Benincasa	1	..	1	1	100
Momordica	25	..	6	7	38
Cucumis	26	..	4	4	15·3
Citrullus	3	..	2	2	66·6
Coccinia	13	..	1	1	7·7
Cucurbita	10	..	3	3	30
Thaldiantha	4	1	1	2	50
Edgaria	1	1	..	1	100
Bryonopsis	2	..	1	1	50
Melothria	54	3	6	11	20·3
Kedrostis	11	..	1	1	9·1
Cerasiocarpum	1	..	1	1	100
Corallocarpus	15	1	2	3	20
Blastania	2	1	1	2	100
Dicaelospermum	1	1	..	1	100
Cyclanthera	39	..	1	1	2·6
Actinostema	4	1	..	1	25
Zanonia	2	..	1	1	50
Gomphogyne	2	2	..	2	100
Gymnostema	3	1	1	2	66·6
Alsomitra	11	2	1	3	27·3
TOTAL	290	37	47	86	29·6

NOMENCLATURE

In the binomial nomenclature of the species, the older obsolete names as given in the *Flora of British India* have been discarded in the present paper. Attempts have been made to ascertain the correct name of a species. According to *International Rules of Botanical Nomenclature*, the name given to a species by the author of its first recorded authentic description has priority over the name or names which subsequently may have been given to it by other authorities, unless the name has to be changed owing to transference of the species to another genus. It sometimes happens that the same names have been given to different species by different authors. Accuracy in describing a species however, could not be often maintained by the authors while describing the same species. Where this has happened according to the *International Rules* the original specific name is retained and two authorities have been given for the change. The author of the original name is first shown in the brackets followed by the author of the new combination. According to the present convention of *International Rules of Botanical Nomenclature* which is however not obligatory, the use of

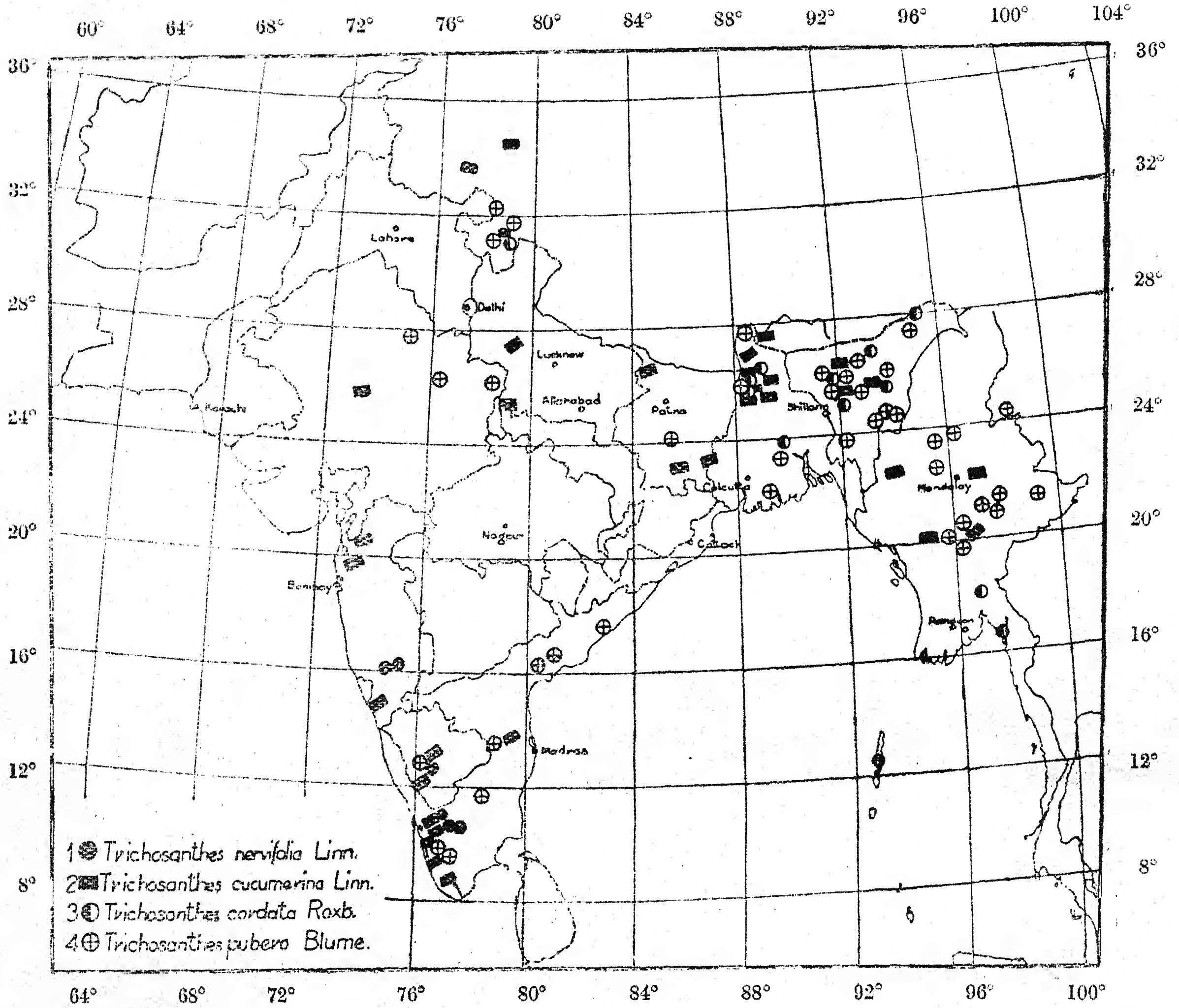

Fig. 2. Distribution of economic cucurbits.

capital letter for the specific name has been abolished except in the cases where the specific name has at sometime been used as a generic name, where the specific name is a genetive singular or an adjectival form of some one's name. This recommendation is not however followed by many applied botanists, who irrespective of their derivation write specific name with a small initial letter. In checking these names in addition to consultation of original papers the following books have often been referred to :

(1) *Index Kewensis*, (2) *Index Londinensis*, (3) *Gamble's Flora of Madras*, (4) Prain's *Bengal Plants*, (5) *Kew Bulletins, etc*.

The following names have been checked and changed :—

syn. *Gymnopetalum integrifolium* Kurz.	*Trichosanthes integrifolia* Kurz.
syn. *Trichosanthes palmata* Roxb.	*Trichosanthes bracteata* Voight.
syn. *Trichosanthes multiloba* C.B. Clarke	*Trichosanthes Wallichiana* Wight.
syn. *Trichosanthes lobata* Roxb.	*Trichosanthes cucumerina* Linn.
syn. *Trichosanthes reniformis* Miq.	(reduced to) *Trichosanthes cucumerina* Linn.

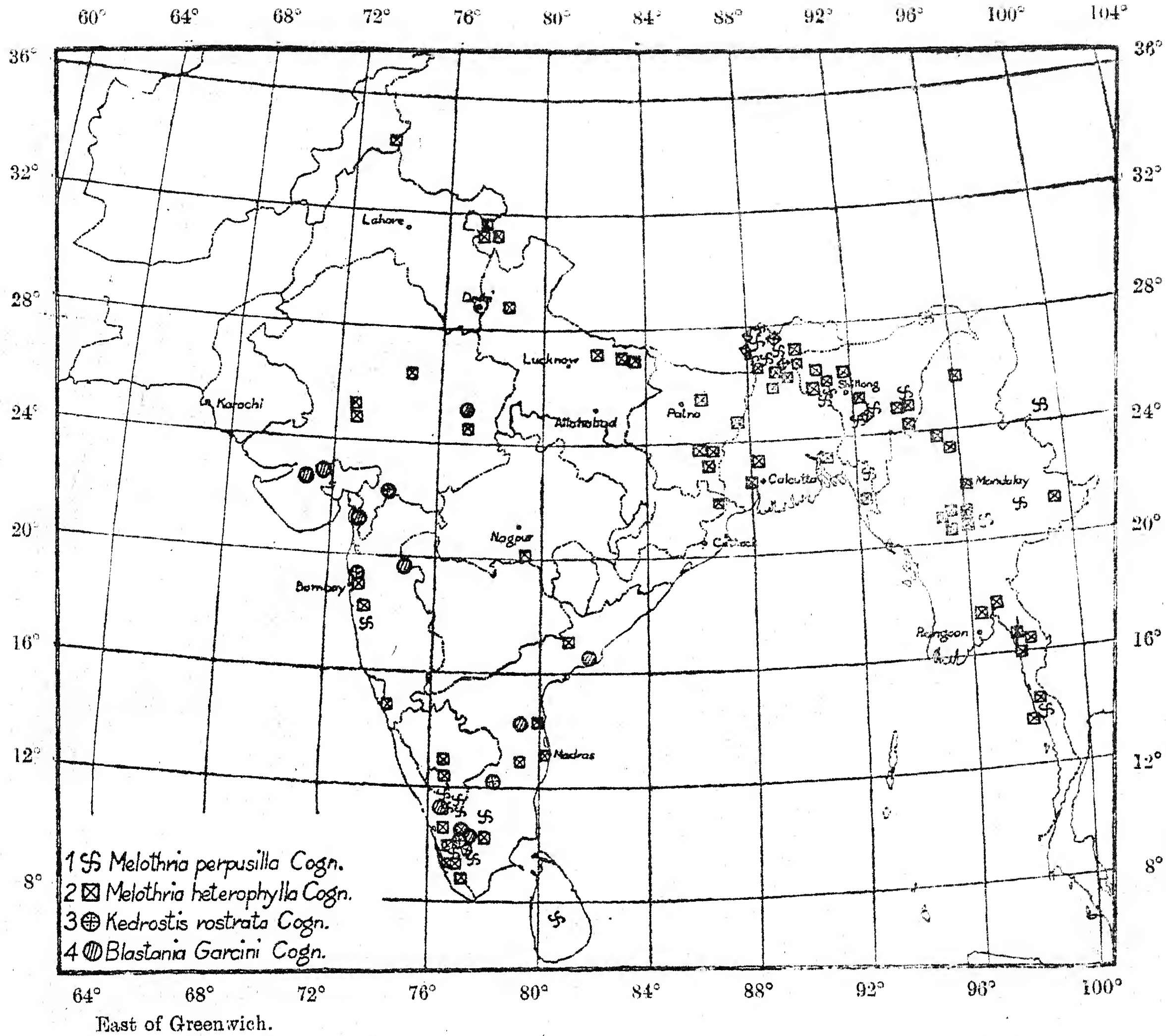

FIG. 3. Distribution of economic cucurbits.

syn. *Cephalendra indica* Maud.	*Coccinia indica* Wight.
syn. *Bryonia laciniosa* Linn	*Bryonopsis laciniosa* Naud.
syn. *Mukia scabrella* Arn.	(reduced to) *Melothria maderaspatana* (L.) Cogn.
syn. *Mukia leiosperma* Thw.	(reduced to) *Melothria leiosperma* (W. & A.) Cogn.
syn. *Zehneria Baueriana* Endl.	(reduced to) *Melothria muronata* (Bl.) Cogn.
syn. *Zehneria Hookeriana* Arn.	(reduced to) *Melothria perpusilla* Cogn.
syn. *Zehneria umbellata* Thw.	(reduced to) *Melothria heterophylla* Cogn.
syn. *Melothria odorata* Hk. f. & T.	*Melothria leucocarpa* Cogn.
syn. *Rhynchocapara foetida* Schrad.	(reduced to) *Kedrostis rostrata* (Rottl.) Cogn.
syn. *Thladiantha dubia* Bunge.	*Thladiantha calcarata* C.B.Clarke
syn. *Ctenolepis Garcini* Naud.	(reduced to) *Blastania Garcini* (L.) Cogn.
syn. *Corallocarpus conocarpa* Hook.	*Corallocarpus conocarpus* Benth. Hook.
syn. *Ctenolepis ceraciformis* Naud.	(reduced to) *Blastania fimbristipula* Hotschy.
syn. *Warea tonglensis* Naud.	(reduced to) *Biswarea tonglensis* (C.B.Clarke)

The following species have been added :

Trichosanthes tricuspidata Lour ; *T. Lepiniana* Cogn ; *T. Thwaitesii* Cogn., *T. anaimlaiensis* Bedd., *T. ovata* Cogn., *T. cuspidata* Lam., *T. Perrottetiana* Cogn., *T. villosula* Blume., *T. brevibracteata* Kundu., *T. majuscula* Kundu, *T. pachyrrhachis* Kundu, *T. khasiana* Kundu, *Momordica macrophylla* Gage., *Cyclanthera pedata* Schrad., *Alsomitra pubigera* Prain,

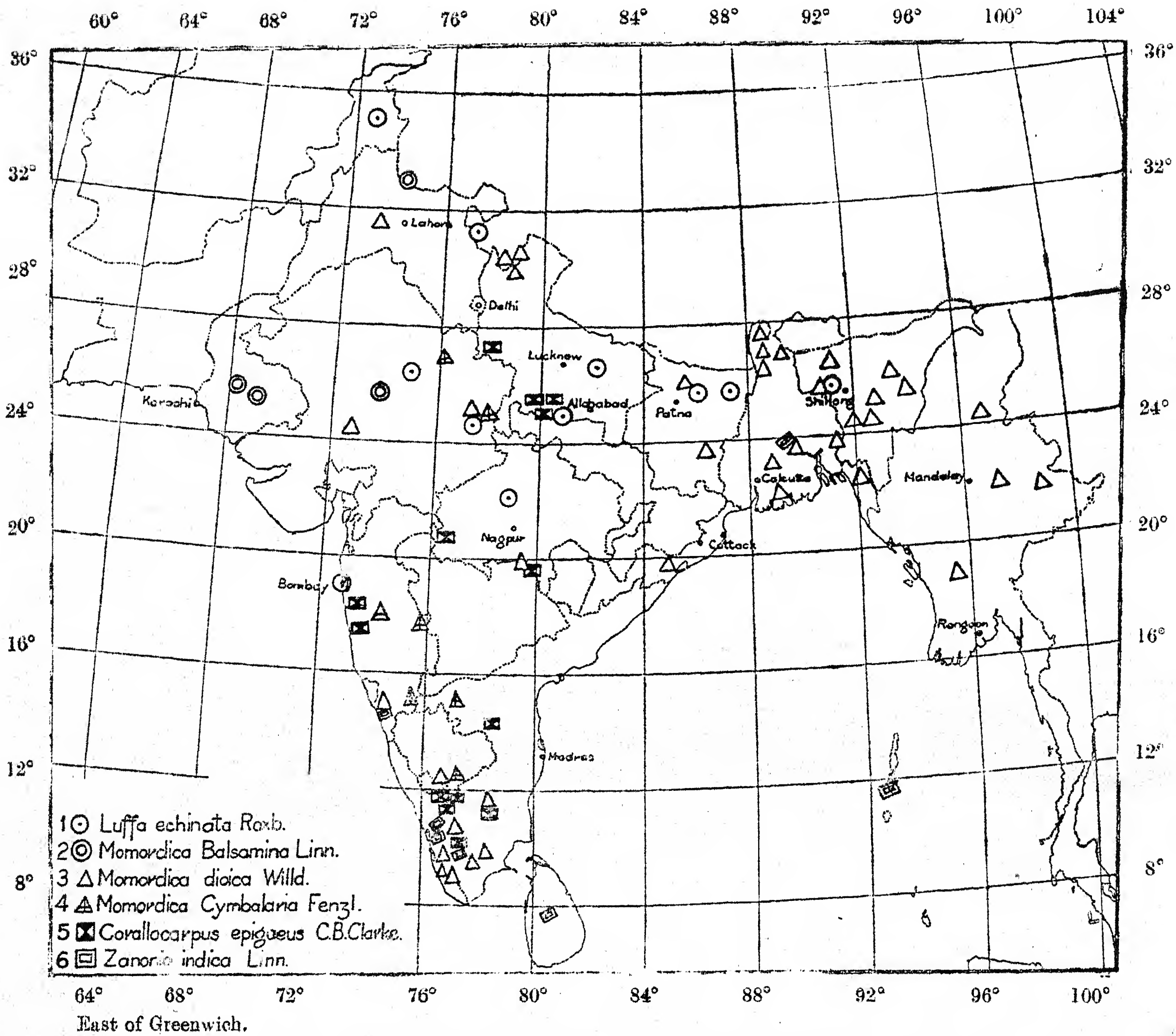

FIG. 4. Distribution of economic cucurbits.

INTERNAL MORPHOLOGY

In almost all the species of Cucurbitaceae the vascular bundles are bicollateral in structure. These bundles are always separated from one another by broad stripes of ground tissue. In the herbaceous species a sclerenchymatous ring which is usually continuous is developed in the cortex; in these forms the vascular bundles are also as a rule arranged in two rings. The sieve tube occurs in the stem outside the florovascular system. A definite type of stoma does not appear in the order. The hair covering consists of (a) simple unicellular or uniseriate structures, the base of which is sometimes surrounded by subsidary cells or (b) spiny trichomes or (c) shortly stalked glandular structures composed of few cells. A very common feature of these order is the occurrence of

cystolith like structures which are found in the cells of the hairs and in the neighbouring cells, whether belonging to the epidermis or the mesophyll.

Leaf

The leaf anatomy opens out a very interesting chapter. The leaves of many species are provided with peculiar glands for the exudation of waste products. In *Lagenaria vulgaris* they are confined to the junction of the petiole and the blade and are bilaterally arranged. In *Cucurbita* the glands are club-shaped and are confined to the lower surface of the leaf, while in *Coccinia* and *Luffa* they are oval shaped and are met with on the undersurface of the leaf. In a right-angular longitudinal section, these glands show a somewhat thickwalled superficial layer of cells enclosing a mass of reserve cells containing sugary solution. A mass of tissue, known as supply-tissue, surrounds the superficial layer of cells in which a number of tracheidal ends are projected symmetrically. These tracheides carry the exuding solution from down below to the leaf end.

Most of the species of Cucurbitaceae have devices for the exudation of surplus water which they absorb from the soil. Hydathodes and water-stomata are, therefore, of general occurrence in many of the species. Sieve-like hydathodal systems have been observed by Chakravarty [1937] in *Cucurbita pepo* provided with pores all around. The genus *Momordica* is however characterized by the presence of calcium carbonate and calcium oxalate in the form of cysloliths and crystals respectively. Anatomical studies [Chakravarty, 1937] of the mid-ribs of cucurbitaceae reveal an interesting phylogenetic relationship of the different species from the evolutionary point of view if the reduction of the number of vascular bundles is considered the principle critarion of evolution. The genus *Trichosanthes* seems to have a striking relationship with the genus *Luffa*. Of the two species of *Trichosanthes* anatomically studied, *Trichosanthes anguina* more closely resembles *Luffa* which has four vascular bundles arranged crosswise, the lowest being the largest and topmost the smallest. From the standpoint of reduction of vascular bundles *Trichosanthes dioica* seems to have been derived from *Trichosanthes anguina*, the topmost bundle of the cross being absent in the former. Moreover, *Trichosanthes anguina* can still be found growing wild, while *Trichosanthes dioica* is never found in a wild state and has undergone wide cultivation. Of the two species of *Luffa* (*L. acutangula and L. aegyptiaca*), *Luffa acutangula* seems to be the more primitive. Here the topmost bundle may be taken to be a compound one made up of two bundles. In *Luffa aegyptiaca* (*L. cylindrica*) the topmost bundle is a perfect single whole and there seems to be a tendency of further reduction of the number of the two intermediate bundles. These two bundles are found joined in the proximal part of the mid-rib and may in course of time be fused and reduced to a single one. *Momordica charantia* seems to have been derived from *Momordica cochinchinensis*. The latter species contains five vascular bundles at the mid-ribs as against only four in the former at the base of the mid-rib coalascing eventually into a single bundle.

Cucumis sativa seems to be more primitive than *Cucumis melo*; of the four vascular bundles of the latter species, three at the top are on the verge of extinction. Loureiro [1790] in his *Flora Cochinchinensis* named *Benincasa hispida* Cogn. *(*B. cerifera* Savi) as *Cucurbita pepo* Lour., while Blume [1826] in his *Bidragen tot de van Nederlandsch-indie* designated it as *Cucurbita ferinosa* Blume. Wallich however in his *Catalogue* No. 6723 renamed it as *Cucurbita hispida* Wall. which from its external appearance seems to have much resemblance with *Cucurbita pepo*. It is remarkable that authors like Loureiro, Blume and Wallich placed *Benincasa hispida* as a species of *Cucurbita*, but the number of vascular bundles (seven) and their elliptical arrangement in *Cucurbita pepo* differ greatly from those of *Benincasa hispida* which has four vascular bundles lying vertically in a straight line. This difference may be explained by the fact that each pair of bundles horizontally placed in the mid-rib of *Cucurbita pepo*, except the basal one which is the largest and fixed, approaches

*Characters common in *Benincasa* and *Cucurbita* are: Large climbing herb, soft hairy tendrils 2-4 fid in *Cucurbita*, but 2-fid in *Benincasa*. Leaves cordate 5-angular or lobed; petioles without glands. Flowers large yellow monoecious, all solitary without bracts. Male, calyx tube campanulate, lobes 5-linear or foliaceous; corolla campanulate 5-lobed; stamens 3 inserted in the calyx tube. Female, calyx and corolla as in the male; ovary oblong; ovules many horizontal; placentas 3, fruits fleshy, large, indehiscent; seeds compressed.

one another and finally fuses to form a single bundle with the result that there are three bundles in a straight line just above the basal one which corresponds with the arrangement in *Benincasa hispida*. *Benincasa* may therefore be regarded as an advanced form of *Cucurbita*.

The petiole of Cucurbitaceae contains isolated vascular bundles. These bundles are arranged in the form of a horseshoe or a circle in transverse section, those of the large size having bicollateral structure. The number of bundles varies both in the initial and characteristic regions.

The stem

The stem is characterized by the presence of bicollateral vascular bundles in two rings and a continuous strengthening ring in the cortex. The xylem contains vessels with very wide lumina and simple perforations. The phlœm groups are composed of sieve tubes with wide lumina. The internal soft bast sometimes shows secondary thickening. The outer cortex is built up of selerenchymatous ring consisting of prosenchymatous elements. This ring of selerenchyma which is usually continuous and often has an undulating course in transverse sections of the stem appears to be present in all the herbaceous members of the order which do not exhibit any considerable amount of growth in thickness. In those species, on the otherhand, which form woody stem, the selerenchymatous ring is wanting, since in this case the mechanical support is afforded by the ring of wood. The formation of cork is rare.

The root

Some members of the order have roots with anomalous structure ; for instance, *Cucurbita* is distinguished by the occurrence of islands of soft bast situated in the wood and connected with the interxylary phlœm of the axis. Cucurbitaceæ mostly possesses a pith containing intraxylary groups of soft bast which subsequently may become converted into inversely oriented vascular bundles.

Cytology

The cytology of the species belonging to Cucurbitaceæ seems not to have been sufficiently studied. Kirkwood [1907] and Kratzer [1918] who have investigated the development of embryosac in a number of species have arrived at the conclusion that the development of the embryosac is of the normal type. Banerjee and Das [1936] working on *Trichosanthes dioica* have also confirmed the findings of Kirwood and Kratzer. The magaspores differentiate out in the third layer of mother cells or are hypodermal in origin. Kirkwood [1907] worked out the process of pollen formation in *Micrampelis alba* and found that the process of chromosome conjugation was of the parasynaptic type. Strasburger [1910] worked on *Bryonia alba* with an idea to determine the sexual mechanism of the plant. Bœnicke [1911] studied the heterotypic cell divisions in *Bryonia dioica*. Later on *Bryonia dioica* was re-investigated cytologically by Meurman [1925] and Lindsay [1936]. Kozhuchow's [1925] investigations were mostly confined to somatic cells of a number of Cucurbitaceous plants. He also determined the chromosome numbers of the species he studied. Castetter [1926] described the meiosis in *Cucurbita pepo*. He proved that cytokinesis takes place by furrowing in this plant. Heimlich [1927] worked out the meiosis in *Cucumis sativus*. Passmore [1930] has given a comprehensive account of the process of pollen formation in *Cucurbita pepo*, *Cucurbita maxima*, *Citrullus vulgaris*, *Luffa aegyptiaca*, *Cucumis melo* and *Cucumis sativus*. He found that the process of chromosome conjugation is of the parasynaptic type in the family Cucurbitacæ. Asana and Sutaria [1932] have given a general account of the pollen formation in *Luffa aegyptiaca* and also determined the chromosome number of some of species. Sinoto [1928] has observed the presence of heteromorphic pair of chromosomes in *Trichosanthes japonica*. But Lindsay [1936] and others have failed to find

any heterochromosome in *Bryonia dioica*. Chromosome numbers in a few species of Cucurbitaceæ are shown in Table II.

TABLE II

Chromosome numbers in a few species of Cucurbitaceæ

Name of species	Chromosome number (n)	Reported by
Melothria punctata Cogn.	12	McKay
Melothria abyssinica	12	McKay
Momordica balsamina Linn.	11	McKay
Luffa ægyptiaca Mill.	13	McKay and Passmore
Ecballium Elaterium A. Rich.	12	McKay
Citrullus colocynalhis Schrad	11	Kozhukhow, Passmore, Whitaker
Cucumis myriocarpus Naud.	12	McKay
Cucumis Melo Linn.	12	Passmore, Kozhukhow and McKay
Benincasa hispida Cogn.	12	McKay
Cucurbita maxima Duchesne	20	Castetter and Passmore
Cucurbita Pepo Linn.	20	Lundegarth
Cyclanthera pedata Schrad.	16	McKay
Trichosanthesdioica Roxb.	11	Banerji and Das
Trichosanthes Anguina Linn.	11	Banerji and Das

AFFINITIES AND SYSTEMATIC POSITION

There is a great deal of controversy as to the systematic position of this family. Hitherto, Cucurbitacea has been by an universal consent arranged among families with one-celled ovary and parietal placenta, but it is difficult to agree with it, if the explanation about the formation of pepo as discussed before be found correct, since in the fruit, we have a peculiarity of structure by which the family is separated from every other known order of the vegetable kingdom. Lindley (1836) places it in his Epigynous group amongst a suit of orders possessing axile placentation, but distinguished the Cucurbitaceae by possession sinuous stamens, unisexual flowers and exalbuminous seeds. Endlicher (ex Wight, 1850) places it between Begoniaceæ and Passifloraceæ, the affinities of which have not been clearly understood. The very intimate union of the calyx and corolla which led Jussieu (1789) to view the flowers as apetalous and to range the order under his class Apetalæ, is a point of structure which cannot be overlooked in determining the affinities. Wight [1850] thinks that though Jussieu's view on this point is essentially incorrect yet it suggests a relationship with Euphorbiaceæ in some striking points. As a family, Cucurbitaceæ is distinguished from all others by its stamens but more especially the anthers, the cells of which in most cases are very long, winding upwards and downwards on the external surface of the connective. The structure of the anther, combined with the construction of the ovary and fruit, the habit of the plants and lateral tendrills, widely separates this family from any other families in the vegetable kingdom. Various attempts have, however, been made to find associates near which it may be placed in the system of the plants. Of the families thus selected as relations, some have superior and some inferior fruits and some albuminous and some exalbuminous seeds. The grouping of Cucurbitaceæ in Epigynose, as done by Lindley, is untenable because the other relative groups are distinguished by one-seeded ovary; but as a set-off against this disadvantage, he constructs the alliance of these groups having parietal placenta.

The botanists of the old school like Robert Brown, de Candolle and Naudin placed Cucurbitaceæ with Passifloraceæ among perigynous polypetalous families and this view was supported by Benthum and Hooker. Eichler [1875-78] placed it as an appendage to his series Campanulineæ next to the family Campanulaceæ. In support he advanced arguments that the family possesses typically epigynous and pentamerous flowers and that it has the tendency of union of stamens and that the calyx

which though narrow is often foliaceous in nature. Engler [1916, 1936] while supporting the view advocated by Eichler, has placed the family by itself in a series Cucurbitales next to the series Campanulales. Fairly sounder reasons may, however, be put forward in support of the older view. The structure of the ovule with a large persistent nucellus, and extensive tapetal tissue and two distinct integuments, is a difficult obstacle to overcome and gives it a position amongst the typical sympetalous families, but it seems to find a suitable association with Passifloraceæ and the allied families. In these families there is a tendency of inferior ovary and union of the members of the corolla. Rendle [1938] accepted the position suggested by Hallier [1905] and places Cucurbitaceæ with Begoniaceæ and next to Passifloraceæ. Vuillemin [1923] has, however, opined that Cucurbitaceæ must be relegated to the apetalous group of orders and hence he has classed them with Balanophoraceæ, Rafflesiaceæ, Datiscaceæ, Nepanthaceæ and Aristolochiaceæ. He considers them as apetalous and thinks the corolla is nothing but the inner whorl of the calyx.

The writer is inclined towards the older view of Robert Brown, de Candolle and others as supported by Bentham and Hooker and he is of opinion that apart from other considerations, the evolution of unisexuality from hermaphrodity leads Cucurbitaceæ to a place between Passifloraceæ in which the bisexuality of the reproductive mechanism tends towards the unisexuality and *Begoniaceæ* in which the unisexuality is a dominant factor. The remnants of hermaphrodity with rudimentary stamens in female flowers and rudimentary ovary in the male are still present in a number of genera like *Citrullus*, *Kedrostis*, *Corallocarpus*, *Zanonia*, *Bryonopsis*, *Luffa*, *Momordica*, *Trishosanthes*, *Coccinia*, etc.

MEDICINAL PROPERTIES

Various important medicinal properties are attributed to different members of this family. Some are bitter and some are endowed with aperient properties of remarkable potency.

Active principle, however, varies with different plants and even with their different parts. It is mild in the root of some and the leaves of the young shoots of others but is greatest in the pulp surrounding the seed. The seed however is free in this respect. There is a reason to believe that some at least, if not all the edible varieties, owe their freedom from this property to cultivation, as some of them in the wild state are found to possess it in great intensity. The *Lagenaria vulgaris* or bottle gourd may be cited as an example. It has been recorded that some sailors were poisoned by drinking beer that had been standing in a flask made of one of these gourds. Royle (ex Wight, 1850) also mentions a somewhat similar case in which symptoms of cholera were induced by eating the bitter pulp. These poisonous properties are, however, attributed to the bitter or wild variety of *Lagenaria vulgaris*. The cultivated gourd is quite a wholesome article of food with absolutely no bitter principle in it. The fruits of many of the species of *Cucumis*, to which melon and cucumber belong, are powerfully cathartic; of these *C. Hardwickii* and *C. pseudocolocynthes* are worthy of notice. Even the cucumber, especially the less cultivated varieties in this country, is sometimes known to prove strongly aperient in susceptible constitutions. *Citrallus colocynthes* which yield colocynth is one of the most valuable medicinal plants.

The fruits of some species of *Luffa* are violently cathartic such as *L. echinata* of Roxburgh, while those of *L. acutangula* are a wholesome pot herb. Some of the species of Bryonia, especially *B. alba* and *B. dioica*, have the cathartic properties of the family. Curiously enough, the juice of the root is strongly cathartic and is often employed as such while the young fruits are so free from the property that they are used as a pot herb and greatly resemble asparagus in flavour. The purgative properties of the root have long been known as being equal in power even when dried and powdered to jalap and when fresh much more so. But of all those yet mentioned none approach the *Elaterium* in the concentrated virulence of this quality; a few grains of the pulp are known to bring about symptoms of poisoning immediately.

Such being the predominating quality of the family, it is wise to be cautious in the use of even the best known. Many however are in use as pot herbs. Among these may be mentioned the red gourd *Cucurbita maxima* (*C. hispida* Anist.), the boiled pulp of which somewhat resembles in taste a fine tender carrot. The water melon *Citrullus vulgaris* is so highly esteemed because of the cool refreshing juice of its large fruit. The white gourd (*Benincasa hispida*) is sometimes presented at marriage

feasts as a token of good luck to the wedded pair. The vegetable marrow (*Cucumis ovifera*) is one of the finest culinary vegetables.

All the numerous cultivated varieties of melons and cucumbers are known to be wholesome. Some of the Indian species of *Momordica* seem equally safe. The fruits of several species of *Trichosanthes*, especially those of *T. anguina* and *T. dioica*, are in daily use, but those of *T. palmata* are considered poisonous. *Coccinia indica* (*Momordica monadelpha* Roxb. or *Cephalandra indica* Naud.) is a common vegetable eaten by the poorer classes and its ripe fruits seem to afford a favourite repast to many birds. Notwithstanding the draw-backs mentioned above, this is certainly a most useful family of plants owing to the great size of the fruits and large quantity of nutritious matter available in the edible varieties which, on that account, are largely cultivated in every part of India. The other varieties, although unfit for human consumption as such, are sources of many useful drugs and medicines. Nevertheless, sufficient caution must always be exercised in their use to guard against the evil effects which may ensue.

DESCRIPTION

Cucurbitaceæ Juss

Cucurbitaceæ Juss. Genera, p. 393 ; Ser. in Mem. Soc. phys. Geneve, **3,** part 1, p. 1 and in DC. Prodr. **3,** p. 292 ; Spach. Veg. phan. **6,** p. 183 ; Schrad. Reliq. in Linnæa, **12,** p. 401 ; Aruin. Hook. Jour. of Bot. **3,** p. 271 ; Wight in Ann. and Mag. of Nat. Hist. **8,** p. 260 ; Lindl. Veg. Kingd. **3,** p, 311 ; Naud. in Ann. Sc. nat., Ser. **4,** p. **16,** p. 45, Ser. **5,** p. **5,** p. 26 ; Harv. and Sond. Fl. Cap., **2,** p. 482 ; Benth. & Hook. Gen. Plant. **1,** p. 816 ; Hook. f. in Oliv. Fl. trop. Afr. **2,** p. 521 ; Cogn. in Mart. Fl. Brass., fasc. **78,** p. 1 ; Clarke in Hook. Fl. Brit. Ind., **2,** p. 604.

General character

Scandent or prostrate herbs or shrubs with watery juice, often scabrid ; tendrils mostly present, solitary, lateral, spirally coiled, simple or divided. Leaves alternate, petioled, frequently cordate, simple lobed or pedately divided. Flowers unisexual monœcious or dioecious very rarely hermaphrodite, actinomorphic, yellow or white ; inflorescence, racemed or solitary, less commonly panicled. *Male flower :* calyx tubular, lobes imbricate or open ; limb rotate campanulate or tubular ; sepals 5 (rarely 3) ; corolla polypetalous or gamopetalous lobes imbricate or induplicate-valvate, *Petals 5* inserted at the mouth of about the middle or at the base of calyx tube, usually 3 (sometimes 5 or 2). Stamens free or variously united mostly 3 rarely 1-5. One anther always 1-celled, the others 2-celled, cells often straight or curved, flexuous or conduplicate, connective sometimes crested or produced beyond. Staminodes usually not present. *Female flower :* Calyx, and Coralla as in the male. Ovary inferior (in *Actinostemma* ½ inferior) or very rarely free, unicarpellary but falsely tricarpellary (due to projection of the parietal placenta towards the middle). Placentas often 3, parietal but often meeting in the middle. Style with 3 stigmas, more rarely styles 2-3-4. Ovules many arranged towards the ovarian cells, horizontal, rarely pendulous, sometimes few and pendulous near the top of the ovary (in *Dicœlospermum* 3, erect from the base of the ovary). Fruit generally a berry or fleshy pepo, indehiscent or dehiscent by valves or by a stopple often 1-celled, the seeds being often packed with pulp or fibre. Seeds usually many often compressed, without endosperm, horizontal, pendulous (or in *Dicaelospermum* erect) frequently corrugated or subspinose on the margins. On germination, cotyledons appear above ground as the first green leaves of the plants. In *Cucurbita* the escape of the cotyledon from the seeds is helped by development of a peg upon the lower side of the hypocotyl by which the lower half of the testa is pressed to the ground, while the upper half is raised by the growth of the plumule.

Diagnostic characters

Tendril climbers. Leaves simple, alternate, palmately lobed. Flowers actionomorphic, unisexual monœcious or diœcious. Sepals 5, plysepalous, petals 5, gamopetalous. Stamens 3-5 united in pairs, odd one being free. Anthers free or syngenesious. Ovary inferior, trilocular with parietal placentation. Fruit a pepo or a gourd.

Key to the tribe

A.	Ovules horizontal (or pendulous): Female flowers usually solitary; never panicled. Leaves not divided into distinct leaflets (except rarely in *Thladiantha*)	Cucumerineæ
AA.	Ovules and seeds erect	Orthospermeæ
AAA.	Ovules pendulous. Flowers small, the females in panicles and many flowered racemes. Stamens 5 each with a single small straight anther.	Zanonieæ

Key to genera

I. Tribe—*Cucumerineæ*.

A. Ovules horizontal or rarely pendulous; female flowers usually solitary, never panicled; leaves never divided into distinct leaflets
- B. Anther cells flexuous or conduplicate
  - C. Corolla 5-partite to the base, 5-petalous
    - D. Petals fimbriate at their margins
      - E. Ovules 12, perfect, seeds usually 6, each with an abortive seed attached to its side; calyx tube 3-4 in. long . . . . 1. *Hodgsonia*
      - EE. Ovules and seeds very numerous; calyx tube less than 3 in. long . . . . 2. *Trichosanthes*
    - DD. Petals entire
      - E. Calyx tube of the male flower elongate; stamens inserted within and included in the calyx tube or nearly so
        - F. Seeds many horizontal; tendrils rarely divided . . 3. *Gymnopetalum*
        - FF. Seeds many horizontal. Tendrils 2-3 fid; petiole without gland . . . . 4. *Biswarea*
        - FFF. Seeds many. Tendrils divided; stigma two lobed; petiole with two glands at apex . . . . . . 5. *Lagenaria*
        - FFFF. Seeds 12-18 pendulous . . . . . . 6. *Herpetospermum*
      - EE. Calyx tube of the male flowers short
        - F. Stamens inserted at the mouth of the calyx; filaments exerted anthers free
          - G. Fruit dry endocarp fibrous, opening by a stopple; male flowers partly in raceme . . . . 7. *Luffa*
          - GG. Fruit soft, endocarp fleshy, indehiscent; male and female flowers alike, solitary . . . . 8. *Benincasa*
        - FF. Stamens inserted below the mouth of the calyx tube; anthers more or less cohering
          - G. Calyx with 2-3 scales at its base; male flowers with usually a large enveloping bract; tendrils simple; leaves with peculiar cystoliths in the undersurface . . . . . 9. *Momordica*
          - GG. Calyx without scales at the base; male flower with two enveloping bract
            - H. Connective produced beyond the anther cells; tendrils simple . . . . 10. *Cucumis*
            - HH. Connective not produced; tendrils 2-3 fid . . . 11 *Citrullus*
  - CC. Corolla campanulate, not divided more than half way down
    - D. Flowers white; tendrils simple . . . . 12. *Coccinia*
    - DD. Flowers yellow; tendrils divided . . . . 13. *Cucurbita*
- BB. Anther cells straight (or in *Bryonia* slightly curved)
  - C. Flowers large deep yellow, male almost racemose
    - D. Calyx tube short; seeds innumerable . . . . . . 14. *Thladiantha*
    - DD. Calyx tube elongate; seeds 3-9 . . . . 15. *Edgaria*
  - CC. Flowers not large, yellow, male racemose or pedicles not stout
    - D. Male and female pedicle alike one flowered, clustered; tendrils bifid . . . . 16. *Bryonopsis*
    - DD. Male flowers cymose or subumbellate or racemed
      - E. Bracts non-ciliated if any
        - F. Fruit not circumcise
          - G. Fruit on a carpellary peduncle; connective produced . 17. *Melothria*
          - GG. Fruit sessile and beaked . . . . 18. *Kedrostis*
          - GGG. Fruit subsessile indehiscent . . . . . . 19. *Cerasiocarpum*
        - FF. Fruit circumcise, near the base . . . . . . 20. *Corallocarpus*
      - EE. Ciliate bracts, resembling stipules at the base of the petiole . 21. *Blastania*

II. Tribe—Orthospermea

AA. Ovules erect or ascending	
B. Stamens 3, free, inserted on the calyx tube	22. *Dicaelospermum*
BB. Stamens united in a central column, filaments short . . .	23. *Cyclanthera*

III. Tribe—Zanonieae

AAA. Ovules pendulous. Flowers small, the females in panicles or many flowered racemes. Stamens 5, free, each with single small straight anther	
B. Leaves not divided into separate leaflets	
C. Fruit small circumcise; leaves serrate	24. *Actinostemma*
CC. Fruit long clavate; leaves subentire	25. *Zanonia*
BB. Leaves pedately divided into 3-5 leaflets	
C. Fruit trigonous obovoid; leaflets serrate. Tendrils bifid . .	26. *Gomphogyne*
CC. Fruit pea-like; leaflets serrate; tendrils simple	27. *Gynostemma*
CCC. Fruit elongate clavate; leaflets entire; tendrils simple or 2-fid .	28. *Alsomitra*

1. *Hodgsonia*

Hodgsonia Hook. f. & Thoms. in Proc. Linn. Soc. (1853) 257; Hook. f. Illustr. of Him. Pl., tab. 1-3; Naud. in Fl. des Serres, 12, p. 153; Benth. et Hook. Gen., **1,** p. 821; Clarke in Hook. f. Fl. Brit. Ind. **2,** p. 606.

A large climbing shrub. Leaves coriaceous 3-5 lobed; tendrils often 2-3 fid. Flowers large diœcious. Inflorescence—staminate flowers, racemose, long; bracts oblong entire, deciduous; pistillate flowers solitary. *Male flowers*: calyx tube elongate, mouth shortly campanulate, limbs pentagonus, short. Corolla rotate, 5-partite. connate at the base, segments obcuneate truncate, very long, fimbriate. Stamens 3, filaments inconspicuous; anthers exerted, connate, liner, one 1-celled, the other two 2-celled, cells conduplicate. *Female flowers*: solitary. Calyx and corolla as in the male. Ovary globose one-locular; style long, stigmas 3-lobed, lobes 2-fid exerted. Ovules 12, placenta 3, parietal with pair of ovules, attached on each side, horizontal, fruit large depressed globular, 12 grooved, flesh hard; perfect seeds usually six each having a rudimentary or barren seed attached to its side, seeds flat ellipsoid.

Hodgsonia heteroclita H.f. & T. l. c.; Kurz. in Journ. As. Soc. 1877, pt. ii; Hk. f. Ill. l. c. Himal. Pl. t. 1, 23; *Trichosanthes heteroclita* Roxb. Fl. Ind. iii 705; *T. grandiflora*, Wall. Cat. 6685 not of Blume.

Vern. *Goolus* (Sylhet).

Stem extending up to 100 ft. Leaves alternate petiolate, 3-5 lobed, 3-5 nerved smooth on both sides, lobes entire, oblong or triangularly ovate, acuminate. Petioles shorter than the leaves, nearly round, reddish and smooth. Stipules solitary subaxillary, thick short, conical, coloured. *Male flowers*: racemes deep brown, axillary, about the length of the leaves, bearing several alternate, subsessile, very large flowers near the apex. Bracts solitary, oblong acute thick and firm, about $\frac{1}{2}$ inch in length. Calyx often rusty-pubescent outside, tube 2-3 by $\frac{3}{8}$ in. Corolla 5-partite inserted at the mouth of the calyx; segments subcordate, retuse with an acute point at the centre, corolla lobes 2 in., brown, villous, 3 nerved outside, white tinged with yellow inside. Stamens three arising from the mouth of the calyx tube; anthers united forming a broad inverted cone; variously grooved. *Female flowers*: calyx and corolla as in the male. Ovary inferior, broad cordate, deep brown, one-celled containing six pairs of ovules attached to the base of the parietal placentas. Style as long as the calyx tube and adhering to it, except on the base and apex. Stigma large three lobed; lobes emerginate. Berry spheroidal, somewhat villous, apex sometimes pointed, about 5-6 inches in diameter when dry, brittle, one-celled. Mature seeds 6; seeds 2-3 by $1\frac{1}{2}$ in. convex or circular on the exterior edge, apex rounded and the base less so, the abortive seeds much smaller, but of the same form. Embroyo erect. Cotyledons thick firm, white. Plumule of two unequal lobes. Radicle conical. Flowers December to August.

Habitat

Sikkim; alt. 0-4,000 ft.; Assam. Khasia Mts. alt. up to 3,000 ft. East Bengal and Chittagong: Pegu Martaban; Kurz. Pinang and Malacca.

Occurrence

A native of the eastern parts of Bengal and Assam. From Sylhet Mr Robertkith Dick, the Judge of that district, sent plants to the Royal Botanic Garden, Calcutta, in 1805 where they blossomed during the greater part of the year and ripened in October. They grew to great lengths and remained alive for a number of years.

Sikkim Himalaya . . .	Sikkim 1-5,000 ft., Coll. J. D. Hooker; hot valleys below Darjeeling 2,000 ft., July 1862, Coll. T. Anderson M. D.; Balasun, Sikkim, 21-4-57.
Assam	Helio hill, N. E. of Lungleh, 3,700 ft., S. Lushai Hills April 3, 1899, Coll. A. T. Gage; Dibrugarh bazar 18-11-11, Abor Expedition I. H. Burkill; Aimamura, Coll. Dewar; Tingali Bam Jungle, March 1899, Dr. Prain's collector; Pobomukh, 15-12-11, Abor Expedition, Coll. J. H. Burkill; Rajabari, 13 April, collected by Reporter on Economic Products, Government of India; Ehekiajuli jungle, April 1902, Coll. A. C. Chatterjee; Golaghat, 1891, Dr. King's collector; Nazira 250 ft., Sibsagar, Coll. C. B. Clarke; Biknee 2,000 ft., Khasia and Jaintia Hills, 1878, Coll. Geo. Gallatly; Khasia 1-4,000 ft., Coll. J. D. Hooker and T. Thomson.
Burma	Plumedal hills 3,000 ft., above the village, Pegu, Coll. S. Kurz; Choungmenahchg, Coll. S. Kurz; Kachin Hills, 1,300-2,000 ft., 28-3-97, Coll. E. Pottinger R.A.
Wall. Cat.	Wall. Cat. 6684 B, Sylhet; Wall Cat. 6685, Penang; Wall. Cat. 6684 A, Goalpara (Assam); Royal Bot. Garden, Calcutta, Wall. Cat. 6684 C.
Bengal	Rangamati, Chittagong Hill Tracts, 1876; Coll. J. L. Lister.
Malay Peninsula . . .	Setolanjet, Sumatra, 5th Aug., 1921; Kaula Manis Kelantan, 5th February 1923; Laurut, Perak, 100-500 ft., 1883, Coll. Dr. King's collector; Batu Togh, 200 ft., Perak; Malay, A. C. Maingay; Perak, Coll. Rev. Father Scortechini; Thujung, March 1884, Rev. B. Scortechini.

2. *Trichosanthes*

Trichosanthes Linn. Gen. p. 295; Reich. Gen. p. 503; Thunb. Fl. Jap. p. 322; Juss. Gen. p. 396; Lour. Fl. Cochinch. p. 588; Willd. Spec. **4,** p. 598; Blume Bijdr. p. 932; Ser. in DC. Prodr. **3,** p. 3131; Roxb. Fl. Ind. **3,** p. 701; Wight et Arn. Prodr. 1, p. 349; Meisn. Gen. p. 127 (91); Spach veg. phan. 6, p. 192; Schrad. Reliq. in Linn. 12, p. 405; Endl. Gen. p. 939; Arn. in Hook. Journ. of Bot. **3,** p. 277; Wight in Ann. and Mag. of Nat. Hist. **8,** p. 269; Duch. in Orb. Dict. **12,** p. 658; Miq. Fl. Ind. Bat. **1,** part 1, p. 674; Naud. in Ann. sc. Nat. ser. **4,** p. 18, p. 188; Benth. et Hook. Gen. Plant **1,** p. 821; C.B. Clarke in Hook. f. Fl. Brit. Ind. **2,** p. 606.—Anguina Micheli Nov. plant. Gen. p. 12, tab. 9 (1729).—Poppya Rumph. Herb. Amb. **5.** p. 414 (1747); Neck. Elem. **1,** p. 241 (non Roem.).—Cucumeroides Gartn. Fruct. **2,** p. 485 (1791).—Involucraria Ser. in Mem. Soc. phys. Geneve, **3,** part 1, p. 25, tab. 5 (1825) et in DC. Prodr. 3, p. 318; G. Don Gen. syst. 3, p. 42; Meisn. Gen. p. 127 (91); Roem. Syn. fasc. **2,** p. 97.

Scandent herbs. Leaves entire or 3-9 lobed, denticulate; tendrils single or 2-5 fid. Flowers diœcious, sometimes monœcious, white. *Male flowers*: usually racemose (rarely solitary), often bracteolate, calyx tube cylindric, dialated above, 5-lobed. Corolla 5-lobed; lobes long, fimbriate. Stamens 3, inserted in the calyx tube; filaments very short; anthers almost included, connate (free in *Trichosanthes dioica*) one 1-celled, the others 2-celled the cells conduplicate; connective narrow not produced. Rudimentary ovaries 3, filiform. *Female flowers*: solitary, calyx and corolla as in the male. Staminodes o. Ovary inferior, ovoid or fusiform, 1-celled, placentas 3, parietal; ovules very many, horizontal or semi-pendulous; style slender stigmas 3, entire or bifid. Fruit fleshy, globose, ovoid or fusiform, indehiscent, many seeded, usually smooth and glabrous. Seeds packed in pulp, ellipsoid, sometimes angular.

Habitat

Tropical Asia, N. Australia, Polynesia; Species 40.

KEY TO THE SPECIES

I. Male flowers in racemes

A. Seeds much compressed, sometimes oblong, nonbelted
  B. Leaves entire
    C. Male racemes few flowered calyx teeth short . . . . . 1. *T. nervifolia*
    CC. Male racemes many flowered calyx teeth long . . . . . 2. *T. cuspidata*
  BB. Leaves lobed
    C. Male racemes ebracteate . . . . 3. *T. cucumerina*
    CC. Male recemes with minute bracts
      D. Pedicels of the flowers much shorter than flowers .
        E. Fruits very long twisted . . . . 4. *T. Anguina*
        EE. Fruit ovoid ellipsoid . . . . 5. *T. pachyrrhachis*
        EEE. Fruit small ovate acute, leaves small . . . . . 6. *T. brevibracteata*
      DD.. Pedicles of the flowers long
        E. Leaves glabrous on both sides . . . . 7. *T. Perrottetiana*
        EE. Leaves lower surface densely villose . . . . . . 8. *T. villosula*
    CCC. Male racemes with large bracts
      D. Leaves at base truncate or narrowed
        E. Leaves ovate oblong bracts petiolate oblong lanceolate . 9. *T. truncata*
        EE. Leaves broadly ovate, bracts sessile ovate . . . . . 10. *T. ovata*
      DD. Leaves at base deeply cordate
        E. Female flowers solitary, ebracteate
          F. Calyx segments entire
            G. Leaves entire, ovate triangular; bracts entire . . 11. *T. cordata*
            GG. Leaves shortly lobed; bracts crenate or incised
              H. Leaves not hairy on the upper surface . . . 12. *T. Wallichiana*
              HH. Leaves hairy at nerves on upper surface
                I. Leaves large 5-lobed . . . . 13. *T. majuscula*
                II. Leaves small, 9-15 lobed . . . . . . 14. *T. khasiana*
          FF. Calyx segments dentate or lacinate
            G. Bracts oblong lanceolate subentire . . . . . 15. *T. tricuspidata*
            GG. Bracts broad, dentate or incised
              H. Calyx segments shortly dentate . . . . . 16. *T. pubera (bracteata)*
              HH. Calyx segments deeply 3-5 lobed . . . . . 17. *T.* Lepiniana
        EE. Female flowers racemose, bracteate . . . . . . 18. *T. anamalaiensis*

AA. Seeds turgid with thick longitudinal belts
  B. Leaves deeply trilobed . . . . 19. *T. himalensis*
  BB. Leaves entire . . . . 20. *T. dicaelospermum*

II. Male and female flower solitary

A. Leaves at base cordate, margin-dentate
  B. Leaves cordate, ovate oblong; petals fimbriate . . . . . 21. *T. dioica*
  BB. Leaves reniform; petals entire or lacinate . . . . . . 22. *T. integrifolia*
AA. Leaves at base round, margin entire . . . . 23. *T. Thwaitesii*

1. ***Trichosanthes nervifolia*** Linn. sp. Pl. 1008; *Trichosanthes cuspidata* Lamk.; Trim. Ceyl. **2,** 244; Vern.: Hind. *Parvar, Paval;* Beng. *Potol*; Tam. *Kombu-pudalai;* Tl. *Kummu-potta;* Kan. *Podla Kayi.*

Perennial; stems twining glabrous somewhat woody below, much branched; branches slender, striate, glabrous diœcious. Tendrils 2-fid, glabrous. Leaves entire 2-4 by 1-$2\frac{1}{2}$ in. ovate oblong (not lobed), acute, mucronate, the margins minutely and remotely denticulate, glabrous on both surfaces, dark green above, paler beneath, base cordate; main nerves 3, from the base, the two lateral ones not quite reaching the apex, with strong secondary nerves on the outside, the lowest pair of secondary nerves conspicuously branching into the basal lobes of the leaves at either side of the sinus; petiole $\frac{1}{2}$-1 in. long. *Male flowers*: in axillary 4-10 flowered corymbose racemes; peduncles slender, sulcate, 1-$2\frac{1}{2}$ in. long; petioles $\frac{1}{5}$-$\frac{1}{3}$ in. long; bracts minute caducous. Calyx tube puberulous, $\frac{2}{3}$-$1\frac{1}{4}$ in. long., very narrow, about $\frac{1}{8}$ in. wide at the mouth and $\frac{1}{10}$ in. wide in the middle; teeth short linear, acute $\frac{1}{16}$-$\frac{1}{10}$ in. long. Petals ovate-oblong, acute, fimbriæ at the apex much branched

and much longer than the blade of the petal. *Female flowers*: axillary, solitary, on both peduncles. Calyx tube nearly 2 in. long, much produced above the ovary. Fruit 1½-3 in. long, ellipsoid, shortly beaked tapering to both ends, green with white lines when immature, scarlet when ripe; pericarp thin. Seeds semi-ellipsoid ⅜-½ in. long, compressed, thickened at the margins each enclosed in an envelope of scarlet pulp. Flowers November to December.

Habitat

Deccan Peninsula; Quilon, Wight; Coorg (tropial region), G. Thomson; Ceylon, not uncommon up to 5,000 ft., Thwaites.

The species is restricted principally to Peninsular India and Ceylon, even there it is not very widely distributed.

Medicinal uses

The medicinal properties of this species are allied to that of *Trichoanthes dioica.*

Occurrence

Peninsular India . . . Kavalay Cochin 2,000 ft., November 1910, Coll. A. Meebold; Nilgiri, Coll. G. Thomson; Astoli, Belgaum Dist., Nov. 21, 1889, Coll. W. A. Talbot.

2. ***Trichosanthes cuspidata*** Lam. Encycl 1,188; Meth. Bot. 1, p. 188; Cognaiaux (1881), p. 357. Ser. in DC. Prodr. **3,** p. 314; W. & Arn. Prodr. 1, p. 349; Roem. Syn. fasc. **2,** p. 95; Rheed. Hort. Malab. **8,** p. 31, tab. 16; *T. caudata* Willd. sp. pl. **4,** p. 600.

Stem slender, elongate, branched, channeled, glabrous, smooth. Petiole slender, furrowed, glabrous ½-1 cm. long. Leaves upper surface deep green, lower surface pale green, 8-10 cm. long, 4-5 cm. broad base 5-nerved; veins not prominent, lower prominent and thinly reticulate; lobes at the base broadly round, 1 cm. deep. Tendril delicate, short, furrowed, glabrous bifid. Common male peduncle slender, furrowed, glabrous. Male racemes many flowered. Flowers at the base almost continuous, 4-7 mm.; bracteole about ½ mm. long. Calyx tube filiform, apex dilated, 12-14 mm. long, apex 1½ mm. and middle ⅓-½ mm. broad; teeth erect 2-2½ mm. long. Staminal filaments ½ mm. long, anther hard oblong linear, 3½ mm. long, 1 mm. broad. Fruit glabrous, smooth turbinate-ovate, apex long appendiculate.

Habitat

In Eastern India at Quilon (Wight n. 1135 in Herb. Kew. deless. Hort Petrot., Vindar). From Cogniaux Cucurbita p. 357.

3. ***Trichosanthes cucumerina*** Linn. Sp. pl. 1008. Roxb. Fl. Ind. iii 702; Wall. Cat. 6190 A.B.C.D. E.; Blume Bijd. 933; Dalz. & Gibs. Bomb. Fl. 102; Miq. Fl. Ind. Bat. i, pt. i 676; Naud. in Ann. Sc. Nat. Ser. 4, xviii 191; Kurz in Journ. As. Soc. 1877, pt. ii, 98. *Trichosanthes lobata* Roxb. *T. laciniosa* Klein in Herb. Rottler; *Bryonia umbellata* Wall. Cat. 66770 D; *Cucumis Missonis* Wall. Cat. 6728; *Trichosanthes reniformis* Miq.

Vern. Sans. *Patola;* Beng. *Banchichinga, banpatol;* Hind. *Jangli-chikanda;* N. W. F. *Jangli chichinda, banpatol, kandori;* Pb. *Ban-goal kakri, Moaakin;* Bomb. *pan parul, jangli padavala, Kadu-padavala;* Mar. *Ranachapadavali, Kadupedavala, peypwal, pedel;* Tel. *Adavipatla, Chedupotla, patolame;* Kan. *Bettadu-padavala;* Malay. *Kaippam-patolam;* Burma. *Topelenmoye.*

A pretty extensive climbing annual dioecious or monœcious; stamens 12-15 ft. long, slender, furrowed slightly hairy, subglabrous, leafy. Tendrils 2-3 (usually 3) fid. Leaves 2-3 in. long, usually little broader than long, orbicular-reniform or broadly ovate, distantly denticulate, more or less deeply 5 or less deeply 5 (rarely 3-7) lobed, the lobes broad, acute, glabrous or nearly so above, more or less pubescent, or when old, sometimes scabrid beneath, base deeply cordate the sinus often subrectangular; petioles 1-3 in. long, striate, pubescent. Male flowers in axillary racemes with

sometimes a solitary male flower from the same axil as the raceme; peduncles of the racemes 2-6 in. long, slender, striate bearing 8-15 flowers near the apex; pedicels puberulous, $\frac{1}{3}$-$\frac{3}{4}$ in. long; bracts 0. Calyx tube dilated at the apex, $\frac{3}{4}$-1 in. long, about $\frac{1}{8}$ in. wide at the mouth; teeth short acutely triangular. Petals white $\frac{3}{8}$ in. long, lanceolate oblong, laciniate at the apex. Female flowers axillary, solitary or occasionally a female flower in the same axil as the male peduncle; peduncles of female flowers $\frac{1}{8}$-$\frac{5}{8}$ in. long. Fruit 1-3 in. long; ovoid fusiform, tapering at both ends and with a long sharp beak, green and striped with white when immature, scarlet when ripe; pericarp thin. Seeds semi-ellipsoid, compressed, involved in red pulps. Flowers July to October.

Habitat

Found throughout India and Ceylon; distributed to Malay and N. Australia.

Medicinal uses

The patola of Sanskrit writers, a plant which is mentioned by *Chakradutta* as febrifuge and laxative, is said by Dymock to be referred in Bombay to this species. In Bengal, on the other hand, *Trichosenthes dioica* is believed to be the Sanskrit patola. Whatever this species may be, the species under consideration is supposed to possess several valuable properties. Thus Ainslie writes, 'The tender shoots and dried fruits are very bitter and aperient, and are reckoned amongst the stomachic laxative medicines; they are used in infusion to the extent of 2 ounces twice daily'. In South India, the seeds are considered to be a remedy for disorders of the stomach, antifebrile and anthelmintic; the tender shoots and dried fruits are believed to have the qualities described by Ainslie, and are given in decoction with sugar to assist digestion; the juice of the leaves is thought to be caustic, and the root purgative, the petiole of the leaf in the form of a decoction is a reputed expectorant. According to Dymock, the plant has a reputation as a febrifuge in Bombay and is given in decoction with ginger, chiretta and honey. 'Muhammadan writers described it as cardiac tonic, alterative, antifebrile, and a useful medicine for boils and intestinal worms'. In the Konkan the leaf juice is rubbed over the liver, or the whole body, in remittent fevers. 'The juice of the leaves and fruits is useful in cases of congestion of the liver and bilious headache; it also acts as a laxative.' (Civil Surgeon J. H. Thornton.)

Occurrence

Malay Peninsula	Perak, within 500 ft., open grazing ground, March 1884, Dr. King's collector Java, 1859; Viti and Fiji Isls., Coll. B. Seemann, 1860.
Peninsular India	Koni, Travancore State, 25-8-1913, Coll. C. C. Calder & M. S. Ramaswami; Vellapatti 1,600 ft., Coimbatore Dist. 27-9-1710, Coll. C. E. C. Fischer; Mysore and Carnatic, Coll. G. Thomson; Pimpuyaum, north of Nasik, Bombay 1878; Karwar, North Kanara, 15 July 1883, Coll. W. A. Talbot; Badami, S. India, Sept. 1910, Coll. A. Meebold; Aiyarangal 1,200 ft., Anaimalai, S. India, Coll. C. E. C. Fischer.
Assam	Kobo, Abor Expedition, 18-12-1911, Coll. I. H. Burkill; Assam, Coll. Griffith.
Bengal	Sundribans, 27-8-1897, Coll. Janardan; N. Bengal, between Dingra Ghat and Purnea; W. Bengal in hedges around villages, Coll. S. Kurz.
Bihar	Manbhum Coll. Rev. J. Campbell, base of Pareshnath 13-11-58.
Gangetic Plain	Coll. T. Thomson; Banda, U. P. Coll. Mrs. A. S. Bell; Lucknow, Aug. 1854.
N. W. Himalaya	Near Dehra Dun, July 1882, Coll. Duthie; Coll. P. W. Mackinon; Sagalwas Forest 8,500 ft., Chamba (Punjab) 15-9-99, Coll. Harsukl; Aboo 1868, Aug. 1868, Coll. G. King; Anadru, Aug. 1808, Coll. G. King; Dehra Dun 1869, Coll. G. King; Dalhousie Coll. Dr. Clarke;
C. I.	Guna, Gwalior.
Burma	Maymyo Plateau, 3,500 ft., July-Aug. 1908, Coll. J. H. Lace; Minbu, Sept. 1902, Coll. Shaik Mokim; Shan hills 1892 Abdul Haque; Bhamo 4-2-68, Coll. J. Anderson.
Sikkim Himalaya	1879, Coll. G. King; Selim 1,000 ft., Sikkim, 18 Oct. 1884, Coll. C. B. Clarke; Rungiet 500 ft., Darjeeling 20 Sept. 1869; Rongtsong below Mungpoo 16 Dec. 1876, Coll. A. B.; Sikkim 5,000 ft., 23-9-35, Coll. G. King; Teesta 2,000 ft., 12-8-14, Coll. G. H. Cave; Pankabari 1,000 ft., 8 Aug. 1875, Coll. Gamble; neighbourhood of Kalimpong, January 1901, Coll. P. C. Lyons.
Wall. Cat.	Madras 6728; Monghyr 6691; Royal Bot. Garden, 6693.
Siamese Peninsula	Chingmai 1,000 ft., 7th July 1909, Coll. A. F. T. Kerr.

4. ***Trichosanthes Anguina*** Linn. Sp. Pl. 1008 ; Fl. B.I. **2,** Grah. Cat. p. 78 ; Dalz. & Gibs. Suppl. p. 37 ; Duthie, Field and Gard. Crops, t. 46 ; Woodr. in Journal Bomb. Nat. **11,** (1898) p. 639, & Gard. in Ind. ed. 5, p. 330 ; Watt. Dict. Econ. Prod. 6, part 4, p. 81 ; Kundu. J. Bombay Nat. Hist. Soc. 1942, **43,** 374.

The Snake Gourd. Vern. Sans. *Chichinda ;* Hind. *Parwal, chachinga ;* Beng. *chichinga ;* Uriya. *Chachainda ;* N. W. P. *Jhajhinda ;* Oudh. *Chichinga ;* Pb. *Galar tori, andol, chichinda ;* C. P. *Pudoba ;* Bombay. *Pandolu, padval ;* Burma *Pai-len-mwae.*

Annual, monœcious ; stems 12-15 ft. long, slender, furrowed, slightly hairy, subglabrous. Tendrils 2-3-(usually 3) fid. Leaves 2-5 in. long, usually a little broader than long, orbicular reniform or broadly ovate, distantly denticulate, more or less deeply 5 or less deeply 5-(rarely 3-7) lobed, the lobes broad, glabrous or usually so above, more or less pubescent, or when old, sometimes scabrid beneath, base deeply cordate the sinus often subrectangular ; petiole 1-3 in. long, striate, pubescent. *Male flowers* in axillary racemes, with sometimes a solitary male flower from the same axil as the raceme ; peduncles of the racemes 2-6 in. long, slender, striate bearing 8-15 flowers near the apex ; pedicles puberulous, $\frac{1}{3}$-$\frac{3}{4}$ in. long, bracts 0. Calyx tube dilated at the apex $\frac{3}{4}$-1 in. long, about $\frac{1}{8}$ in. wide at the mouth ; teeth short, acutely triangular. Petals white $\frac{3}{8}$ in. long, lanceolate oblong, laciniate at the apex. *Female flowers* axillary, solitary or occasionally female flowers $\frac{1}{8}$-$\frac{5}{8}$ in. long. Fruit long, often attains a length up to 3 ft., with a thickness of about $1\frac{1}{2}$ in. diameter, somewhat rotate ; when green with white stripes from base to apex. C. B. Clarke is of opinion that it may be a cultivated form of *Trichosanthes cucumerina* with which it conquers in all aspects of its vegetative and reproductive organs except the fruit which is often very long. It is seldom found in wild state and is extensively cultivated throughout India as a rainy season crop. The general treatment and mode of cultivation is the same as that of the cucumber. Flowers June to August.

Habitat

India—cultivated. Distributed to China and Malaya.

Medicinal use

The seeds are considered cooling. Food : The long fruit is cooked and eaten as a vegetable either boiled or in curries. When ripe it turns brilliantly orange in colour. Owing to the resemblance of the fruit with the horn of deer or buffalo this fruit is not taken by certain superstitious Hindu widows of India.

Distribution

Wall. Cat. : Gangachora, 9th June 1809, 6687 C ; 6687 A. U. P. : Banda, vern. *Chachingra*, Aug. 1902, Coll. Mrs. A. S. Bell.

N. W. Himalaya : Dehra Dun July 1884, Coll. Duthie ; Shangai 1860, Coll. Maingay.

5. ***Trichosanthes pachyrrhachis*** Kundu in Journ. Bot. 1939, 77,9. Stem delicate, deeply angled, glabrous or slightly hairy. Leaves membranous, suborbicular or reniform, with a cordate base densely covered with hairs, very shortly 3-5-lobed, lobes subacute ; margin denticulate ; $1\frac{1}{2}$ to $2\frac{1}{2}$ in. in length, 2-3 in. broad. Petiole slender, $\frac{1}{2}$ to $1\frac{1}{2}$ in. length. Tendrils, grooved, puberulous 3-fid. Flowers monœcious. Male racemes 10-15 flowered ; rachis robust, somewhat geniculate, sometimes nearly as thick as the stem succulent, slightly grooved, glabrous 3-$4\frac{1}{2}$ in. long usually flowering from near the base. Pedicels terate, robust, erect slightly puberulous $\frac{1}{8}$ to $\frac{1}{7}$ in. long. Calyx tube short, dilated at the apex. Petals oblong staminal filaments slender very short. Female flowers not seen. Fruiting pedicel solitary 1·5 in. long. Fruits ovoid ellipsoid, attenuate into an acuminate apex ; epicarp thin. Seeds flattened with undulate margins, truncate at the base bidentate at the apex about $\frac{1}{2}$ in. long and $\frac{1}{3}$ in. broad.

Habitat

N. W. India ; Burma ; N. Bengal.

6. ***Trichosanthes brevibracteate*** Kundu in Journ. Bot. 1939, 77,10.

Stem very slender, grooved subglabrous. Leaves membranous, very thin, 3-5 angled or very shortly five-lobed, reniform, apex acute, base cordate emerginate, margin dentate, on the upper surface covered with minute hairs; deep green on the upper surface, pale green on the lower surface; 3·5-7·5 cm. long, 4·5-9 cm. broad, 3-5-nerved at the base; veins very thin prominent on the lower surface. Petiole slender striate, 2-4·5 cm. long. Tendrils slender 2-3-fid. Monœcious or diœcious. Male flowers in racemes. Rachis bearing male flowers slender, striate puberulous 5-10½ cm. long, 5-10 flowered at the apex. Pedicels slender erect or spreading puberulous 5-15 cm. long. Calyx tubular, teeth spreading. Petals oblong 8-10 mm. long 3 mm. broad, staminal filaments slender, about 2 mm. long; anther head oblong 2½ mm. long, 1¼ mm. broad. Female flowers not seen. Fruiting peduncles solitary 8-10 mm. long. Fruit ellipsoid, attenuate into a conical apex 3½-4½ cm. long, 1½-2½ cm. thick with about 7-8 seeds. Seeds flattened, oblong, subglabrous on both surfaces, somewhat undulate at the margins, base and apex truncate, 10 mm. long, 6·6 mm. broad, 2 mm. thick.

Distribution

Karnal, Punjab; Ahmedabad, N. W. India; Koni, Travancore, S. India; Kanara.

7. ***Trichosanthes Perrottetiana*** Cogn. in DC. Monogr. Phan. III 362; leaves subcoraceous, round ovate-suborbicular, margin distantly subulate denticulate, base occasionally deeply emarginate, both sides glabrous or smooth, commonly trilobed at the middle, lobes oblong-triangular, acuminate; male racemes many flowered; pedicels long, base minutely bracteate; calyx shortly puberulous, teeth longish, linear.

Stem often slender, branched, angular, glabrous or slightly puberulous. Petiole slender, striate subglabrous, 5-7 mm. long. Leaves upper surface deep green, lower pale green, dilated at the base, 12-14 cm. long, 10-12 cm. broad, intermediate lobes longish; indentations narrow, acute, base broadly round, 1½-2 cm. deep, 4-5 cm. broad; veins narrow lower veins prominent and reticulate. Tendrils robust elongate, deeply channeled, somewhat puberulous, 3-fid. Common peduncle of the male flowers very slender furrowed, glabrous or slightly puberulous, 10-15 flowered, 15-20 cm. long, pedicles slender, bract 5-10 cm. long; bracts subulate caducous 3-5 mm. long calyx subcylindrical, apex constricted, longitudinally 10-nerved, 1½-2 cm. long, apex 3 mm. and at the middle 1½ mm. broad; teeth erect 4-5 mm. long. Staminal filaments slender 2 mm.; thick. Pistillate 5-6 mm. long. Female flowers unknown.

Habitat

In Eastern India, near Pondichery (Perrottett n. 256 in Herb. Bois and Vindab.).

8. ***Trichosanthes villosula*** Cogn. in DC, Monogr. Phan. III 362 p. 262.

Leaves membranous, round suborbicular, upper surface slightly puberulous or scabrous, lower densely villose hirsute, 5-lobed, lobes ovate oblong, acute or shortly acuminate, male racemes many flowered pedicles long, base minutely bracteate; calyx slightly long villose, with elongate teeth, subulate.

Stem slender, elongate, branched, angularly sulcate, with thin long hairs, Petiole very slender, striate, with sparingly long hairs, 3-6 cm. long. Leaves upper surface bright green, lower surface as the upper, 8-12 cm. long as well as broad; lobes occasionally lobulate, upper nerves thin, lower prominent and reticulate. Tendril robust, elongate, sparingly villose, 3-4 fid. Common peduncle of the male. narrow, channeled. Slightly villose, 12-20 flowered, 10-16 cm. long; pedicles erect ascending subfiliform 2-5 cm. long; bracts subulate, caducous, 1-2 mm. long. Calyx tube subcylindric, upper dilated, apex constricted, longitudinally 10-ribbed, 2-2½ cm. long, apex 5 cm. and at the middle 2 mm. broad; teeth 5-7 mm. long; petals oblong-lanceolate, tri-nerved, acuminate 12-13 mm. long, 3-4 mm. broad; fimbriate, elongate, divided. Stamens: filaments filiform 1-1½ mm. long; anther head sublinear, 5 mm. long 1½ mm. thick. Pistillode 8-9 mm. long. Female flowers unknown.

Habitat

Eastern India at Mount Nilgiri.

9. ***Trichosanthes truncata*** C. B. Clarke. in Hook. f. Fl. Brit. Ind. ii 608.

Stem twining; tendrils 2-3 fid. Leaves ovate from a truncate hastate or obrus (not cordate) base sometimes subpeltate entire or irregularly tricuspid glabrous coriaceous or membranous, polymorphous, sometimes exactly ovate with a rounded sub-entire-margin. Bracts ovate slightly serrate nearly glabrous. Male peduncle 6 in. calyx tube $\frac{3}{4}$-$1\frac{1}{2}$ in. somewhat tomentose without; corolla greenish white. Female plant unknown. Flowers March to June.

Habitat

Occurs in Sikkim upto an elevation of 1,000 ft. Khasia Hills 4,000 ft. H.f. & T.; C. B. Clarke.

Occurence

Sikkim	Rishap 1,500 ft., Darjeeling 10 March 1871, Coll. C. B. Clarke; Sikkim Himalaya Coll. G. King; Riyang, 8-4-1876, Coll. G. King; Joke, Sikkim Coll. S. Kurz, Ramno, Nov. 1857; Gouk 4,000 ft., 15-6-1862, Coll. T. Anderson; Riyang Valley, April 1878, Coll. J. L. Lister.
Assam	Khasia Hills, Coll. Simons; Mount Khasia, 4,000 ft. Coll. J. D. H. & T. T., Konoma, Naga Hils, Aug. 1886, Coll. Dr. D. Prain.
Burma	Kachin Hills, Sadar, March 1898, Coll. Shaik Mokim.

10. ***Trichosanthes ovata*** Cogn. in DC. Monogr. Phan. III, p. 365; leaves membranous, entire, broadly ovate, apex shortly acuminate, base round or truncate, margin minutely remotely denticulate both sides glabrous; tendrils 2-3-fids; male racemes subcapitate, few flowered; bracts ovate, subsessile.

Stem robust elongate, branched, angularly furrowed, glabrous or puberulous. Petiole robust, furrowed, glabrous 3-5 cm. long. Leaves upper surface bright green, lower pale green, 14-18 cm. long, 11-14 cm. broad base trinerved, veins thin lower prominent and reticulate, lateral nerves bifurcate. Tendrils slender, sufficiently elongate, glabrous. Common male peduncle very robust, furrowed, glabrous, apex 6-10-flowered, 10-15 cm. long; pedicels very narrow, shortly villose, 1-2 mm. long; bracts acute, base round, entire or slightly undulate, three nerved, 12-13 mm. long, 8-10 mm. broad. Calyx tube shortly tomentose, upper dilate; teeth erect or reflexed, linear 7-9 mm. long, $1\frac{1}{2}$ mm. broad. Corolla shortly tomentose. Female flowers and fruits unknown.

Habitat

In Sikkim (Thomson in herb. Hort. Petrop. et Lugd. Bat.).

11. ***Trichosanthes cordata*** Roxb. Hort. Beng. 70; Fl. Ind. iii 703; *Trichosanthes tuberosa* Roxb.; *T. palmata* Wall. Cat. 8668 F. partly & C.

Vern. Beng. *Bhui kumra, bhumi kumra, patol.*

An extensive climber. Root tuberous, perennial, growing to the size of a man's head. Stem herbaceous, climbing to a considerable length, five angled, villous or even somewhat scabrous when old. Tendrils opposite, three cleft. Leaves often 6-8 in. alternate, petioled, cordate ovate acute entire or obscurely angular lobed, hairy beneath, dentate serrate. Petiole channeled, a little hairy, scarcely half the length of the leaves. Male peduncles usually paired, the racemed one axillary, solitary as long as the leaves. Bracts alternate, sessile, cuneate, oblong, acute, serrulate, one-flowered. Flowers large white, the fringe of the segments coarser. Female flowers axillary, solitary, short peduncled. Calyx tube $1\frac{1}{2}$ in., densely hairy outside, segments finely acuminate. Fruit spherical, of the size of an orange, and of nearly the same colour, and as in *T. pubera* of which it is much alike, the cells and partitions are very obscure. Seeds numerous, veins immersed in soft gelatinous green pulp. *var. subpedata;* leaves pedately lobed almost to the base, Cachar, C. B. Clarke. Flowers May to August.

Habitat

Met with at the base of the Eastern Himalaya, from Sikkim to Assam and Pegu; frequent in the Khasi; Terai and Assam.

Medicinal uses

The large tuberous root is considered a valuable tonic and is employed as a substitute for Calcumba (Roxburgh). According to Irvine (ex Watt D. E. P.) it is a deobstruent and in Patna the dried flowers are believed to be stimulent in doses of 2 to 5 grains. Taylor states that in Dacca the root, dried and reduced to powder is given in doses of 10 grains in enlargement of the spleen, liver, and abdominal viscera. The fresh root mixed with oil, forms a common application in leprous ulcers.

Occurrence

Peninsular India	Chodavaram—foot of Rampa, Madras Presidency, 7th Aug. 1914, Coll. M. S. Ramswami.
Burma	Martaban, Coll. S. Kurz ; Banks of Sittong, Peu, Coll. S. Kurz.
Assam	Nambar forest 9th May 1895 Collected by the Reporter of Economic Products to the Governmnet of India ; Mount Khasia 0-4,000 ft., Coll. J. D. H. & T.T. ; Nazira 250 ft., Sibsagar, 23 April 1885, Coll. C. B. G. Clarke ; Kohima 4,500 ft., Naga Hills, July 1886, Coll. Dr. D. Prain ; Saikhowa below Sadiya, 25 Aug. 1909, Coll. I. H. Burkill.
Sikkim	Tista valley, 4,500 ft., 5-7-09, Coll. Smith & Cave ; Sikkim, Coll. S. Kurz. ; Darjeeling Terai 500 ft. 12 June 1870, Coll. C. B. Clarke
Bengal	Bhunraj, Dacca 15th Sept., 1868
Malay Peninsula . . .	Singapore, January 1890 ; Pulan Ubain, February 1890, Coll. H. K. R.
Wall. Cat.	Sylhet 6686 B ; R. B. Garden, Calcutta 6686 A
U. P.	Hardwar Dehra Dun, Aug. 1870, Coll. G. King ; near Dehra Dun, July 1882, Coll. J. J. Duthie.

12. ***Trichosanthes Wallichiana*** Wight in Ann. & Mag. Nat. Hist. ser. I. viii (1842) 270 ; *Trichosanthes multiloba* C. B. Clarke ; *T. grandibracteata* Kurz. in Journ. As. Soc. 1877, p. ii, 99 ex descr.

An extensively rambling shrub Diœcious. Leaves deeply (only half way down) palmate in 5 or 3-9 lobes narrowed near their base 3-6 in. diam., usually glabrous beneath or less commonly scabrous with scattered bristles, subcordate at the base ; segments serrate (sometimes lobed) ascending, less divaricate than in *T. palmata*, acute ; petiole 1-3 in., often with several large glands near the apex ; tendrils commonly 3-fid. Bracts ovate or obovate deeply serrate. Male peduncles usually paired, the racemed one 6 in., naked below. Calyx tube 1-2½ in. ; teeth lanceolate, subulate, entire. Fruit 2-4 in., ovoid or oblong acute bright red with orange streaks. Seeds ⅝-¾ in. more or less angular on the margins very many in green pulp. This is rather a variety of *T. pubera* (*T. palmata* Roxb.), the Himalayan large form of which so closely resembles it, that in the absence of the fruit it cannot always be distinguished from it.

Habitat

Sikkim, East Himalaya, Khasia Mts. ; alt. 2,000-6,000 ft. ; plentiful Malacca ? Maingay 671 Distributed to China and Japan.

Occurrence

Burma	Kachin Hills, Upper Burma, January 1898, Coll. Shaik Mokim ; Meywar, Burmah, 6th October 1868, Coll. D. J. Anderson.
Malay Peninsula . . .	Perak, Rev. Father Scortechini ; S. Pahang Aug. 1891, Coll. Huk ; Palan Penang May 1893, Coll. C. Curtis ; Singapore 1893.
Assam	Shillong 6,000 ft., 10 Aug. 1885, Coll. C. B. Clarke ; Shillong, 4 June 1911, Coll. R. K. Das ; Dumpet 30 May 1911, R. K. Das ; Mount Khasia 0-5,000 ft., Coll. J. D. H. & T. T. ; Khasi Hills, 5,000 ft., Tingale Bam jungle March 1899, Coll. Dr. Prain's collector ; Khasi Hills 500 ft., June 1876.
Bihar	Chota Nagpur, Coll. J. J. Wood.
Peninsular India . . .	N. Kanara, Bombay, May 5, 1889, Coll. W. A. Talbot.

Sikkim	Mungapoo, Bhulkiya, 3,000 ft., 18 July 1914, Vern. (Nepal) Indrayni, Coll. C. W. C.; Phadonchen 7,000 ft., 20 Aug. 1910, Coll. W. W. Smith; Sikkim Himalaya, Coll. G. King. Tumlong, 5,500 ft., 10 July 1892, Coll. G. A. Gambie; Sikkim 4,000 ft., 25 January Coll. G. King; Runghee 5,000 ft., Darjeeling, 23 July 1870, Coll. C. B. Clarke; Punkabari 500 ft., Darjeeling 4 Sept. 1879; Sikkim Himalaya, Coll. S. Kurz; Rishap 3,000 ft., Darjeeling 2 Aug. 1870, Coll. C. B. Clarke; East Himalaya, distributed at the Royal Bot. Garden, Kew, Coll. Griffith; Sikkim 2-6,000 ft., Coll. J. D. Hooker.
Assam	Haflong, 2,500 ft., N. Cachar, 2 Nov. 1908, Coll. G. A. Craib.
N. W. Himalaya	Near Mussoorie, 1869, Coll. G. King, Simla 1886 Coll. Collett.; N. W. India Royle.

13. ***Trichosanthes mojuscula*** Kundu in Journ. Bot. 1939, 77, 12.

T. Wallichiana Weight var majuscula Clarke, Cogn. in DC. Monog. III 369; *T. multiloba* Miq. var. majuscula Clarke in Hook. F.B.I. II, H.N.R.

Stem rather stout, elongate, ribbed, glabrous. Leaves large, membranous, glabrous and smooth on the lower surfaces, slightly hairy at the nerves on the upper surface, deeply palmately 5-lobed. Petiole very stout striate or covered with minute hairs, 6-6·8 cm. long. Tendrils stout and woody, ribbed slightly hairy, branched. Male flowers in racemes; rachis short and woody many flowered, grooved. Pedicels short; calyx tube about 6 cm. long 1 cm. broad at the apex, spreading. Female flowers unknown.

Habitat

Khasi Mts., Assam 4,000 ft.

14. ***Trichosanthes Khasiana*** Kundu in Journ. Bot. 1942, 75, 9-12.

Stem robust, elongate, angulate, grooved, glabrous. Leaves membranous, ovate suborbicular. Sparingly hairy at the nerves on the upper surface glabrous on the lower surface, deeply palmately 3-lobed near to the base, sometimes an additional short lobe occur on the side of the each of the lateral ones, 9-15 cm. long 8-13 cm. broad. Petiole stout, striate 2·5-5 cm. long. Male racemes loosely flowered at the apex; rachis very stout. Bracts glabrous, ovate, calyx tube puberulous 4·5-5 cm. long 8·5-10 mm. broad. Peduncle of the female flower 1·5 to 2·5 cm. long. Calyx tube cylindrical ovary fusiform, glabrous. Fruits oblong ellipsoid, slightly tapering on both ends 5-16 in. long. Seeds irregular, margin smooth 10-14 mm. long, 5-8 mm. broad and 2 mm. thick.

Distribution

Khasi mountains.

15. ***Trichosanthes tricuspidata*** Lour. Fl. Cochin **2**, p. 588; edit. Willd. p. 723. Willd. spec. 4,p. 600; Bl. Bijdr. p. 935; Ser. in DC. Prod. 3, p. 305, Roem. Syn. fasc. 2, p. 95; Miq. Fl. Ind. Bat. 1, part 1, p. 676. Leaves coriaceous, broadly ovate-triangular, both sides glabrous or smooth, trilobate, lobes broadly triangular, acute or shortly acuminate, margin entire or obscurely undulate denticulate; tendril trifid; male racemes many flowered; bracts oblong; lanceolate; rarely ovate oblong, subentire or shortly broadly dentate; calyx tube narrowed from apex to base, teeth elongate triangular lanceolate, shortly denticulate.

Stem robust, elongate, branched, furrowed, glabrous, smooth. Petiole very much narrow, angularly furrowed, glabrous 4-6 cm. long. Leaves upper surface intensely green, lower surface pale green; base pedate 5-7 nerved, 10-16 cm. in breadth, lobes divergent, intermediate one longer, indentation between the lobes broad; obtuse or subacute, base angular 2-3 cm. deep; nerves of the upper surface robust, lower surface prominently reticulate. Tendrils robust, elongate, angular, subglabrous. Common peduncle of the male, furrowed, glabrous or slightly puberulous, flowers profuse from middle to the apex, bearing 10-25 flowers, 12-20 cm. long, bracts arising from the base, bracts hard, rigid smooth, ovate oblong, obscurely dentate 1 cm. long, pedicles very much narrow, erect spreading, apex dilated, flexuous 3-8 cm. long; bracts shortly densely villose, many nerved, 2 cm. long; calyx tube shortly densely tomentose 7-8 cm. long, 3-4 cm. broad. Staminal filaments very short, anther head 9-10 mm. long, 2·5-3 cm. broad. Female flowers unknown; fruit ovoid, acute, small yellow. Flowers April to October.

Habitat

Malay Peninsula . . . . Bukil Cheras, Pahang, 10 Oct. 1931, Coll. M. R. Henderson; Polo Boetong, Aug. 1879, Coll. C. Curtis; Singapore, January 1885; Lurul Perak 1,000-1,500 ft., Aug. 1801, Dr. King's collector; Kilan Tujor April 1892, Coll. L. Wray (Jr.)

16. ***Trichosanthes pubera*** Blume, Bidjr. 936; *Trichosanthes palmata* Roxb. Fl. Ind. iii. 704; *T. laciniosa*, Wall Cat. 6689 A.B.; *T. aspera*, Heyne in Herb. Rottler; *T. tricuspis* Miq. Fl. Ind. Bat. i. pt. i, 679; *T. cordata* Wall Cat. 6686 exel. A. and B.; *T. anguina* Wall. Cat. 6687, F partly; *T. bracteata*, Voigt Hort. Sub. Calc. (1845) p. 58; *Cucurbita Melopepo*, Wall. Cat. 6725; *Involucraria Wallichii* Seringe in DC. Prodr. iii 318; *Bryonia palmata* Wall. Cat. 6711 F.

Vern. Sans.-*Mahakala*; Hind.-*Lal-Indrayan, indrayan, makal*; Beng.-*Makal*; N.W.P.-*Indrayan, makhal, parwar, palwal*; Kumaon-*Indrayan*; Bomb.-*Kaundal*; Mar.-Kavandala Tam.-*Korattai, uncoruthai*; Telegu-*Mahakavaduta*; Kan.-*Avagude-hannu*; Arb.-*Aubghol*; Pers.-*Hhnsle-Surkh.*

An extensive climber, often attaining a height of 30 ft.; stamens robust woody below, branched, grooved, the older light green with scabrous spots, the younger smooth, green. Tendrils 2, more commonly 3 cleft. Leaves 2½-5 in. long and about as long as broad, variable usually palmately 3-5 lobed to about the middle (more or less), dark green above, paler beneath, frequently with dark coloured circular gland scattered along the lower side, glabrous, often scabrous with smaller scales above and on the nerves beneath, base cordate; lobes usually ovate oblong, acute, more or less dentate or serrate; petioles 1-3 in. long, striate, puberulous or at length glabrous. *Male flowers*: in axillary 5-10 flowered racemes 6-9 in. long (rarely solitary); pedicles thick, erect, very short; bracts 1 in. long and more, broadly ovate, palegreen, many nerved, fringed dotted with dark green glandular spots. Calyx tube 1½ in. long pubescent, longitudinally striate, teeth lanceolate erect or spreading, laciniate. Petals 1 in. long wedge-shaped, fringed, exceeding the calyx tube. Filaments slightly villous. *Female flowers*: axillary solitary; peduncles less than 1 in. long. Fruit 1·5-2 in. diam., globose red when ripe, strreaked with 10 orange streaks pericarp thick; seeds numerous ⅜-·5 in. long, ellipsoid, smooth slightly attenuated at the base, not margined.

Habitat

India—very common in all moist thickets, ascending to 5,000 ft., distributed to Ceylon, Malaya, China, Japan, N. Australia. Var. I. *Scotanthus C. B. Clarke*: calyx teeth broad lanceolate entire, petals nearly destitute of fimbriations especially in the females. Var. II. *tomentosa* Heyne in Herb. Rottler; leaves tomentose beneath divided not more than half way down. This variety rather look like a good species but the fruit and seed are as in var. 1., and it closely resembles the Australian *T. subvelutina* Muell. in Herb. referred to *T. palmata* by Benthum. The distribution of *T. palmata* is extended to Japan on the faith of two examples collected by Mexmowioz. They belong to the commonest Bengal type *T. pubra* but bear the name *T. japonica* Regal, which in Regal Ind. Sem. 1868, p. 90, is said to have solitary male flowers and has been referred by Benthum and Hooker to the neighbourhood of *T. cucumerina.* A *trichosanthes* collected in Mergui by Griffith No. 759 (No. 2532 Kew Distrib.) has the leaves with short hair beneath otherwise resembles the var. *tomentosa.*

Distribution

Sikkim, East Himalaya and Khasi Hills, alt. 2,000-6,000 ft.; plentiful. Malacca, China, Bhamo and Japan.

Medicinal and other properties

Fruit finely powdered and thoroughly mixed up with coconut oil, is considered a valuable application in cleaning and healing those offensive sores which sometimes takes place inside the ears.*

* Watt's *D. E. P.* 6, (2), 84.

The same preparation is supposed to have beneficial curative properties in ozæna when poured up the nostrils. The root is described by Wight as useful in inflamation of the lungs in cattle. O'Shaughnessy* was induced by the singularly bitter taste of the rind to make experiments with a view to ascertaining whether it possesses purgative, tonic or aperient properties but given in three-grain doses thrice daily it was found to produce no sensible effect (Beng. Dispens). Dymock† states that natives in Bombay sometimes smoke the fruit as a remedy for asthma. The root with an equal proportion of colocynth root is rubbed into a paste and applied to carbuncles ; combined with equal portions of the three myrobalans and turmeric, it affords an infusion which, when flavoured with honey is given in gonorrhœa cases (*Materia Medica West Ind.*). The juice of the fruit or the root bark boiled with gingelly oil, is used with good effect as a bath oil for the relief of long standing or recurrent attacks of headache (Surgeon Major W. R. Thompson, C.I.E., Madras).

The bright-red fruit of the wild plant is non-eatable owing to its severely drastic properties, but, under cultivation the fruit becomes a wholesome vegetable when well-boiled. At the Cape of Good Hope its poisonous properties appeared to be removed by pickling (*J. Agric. Hort. Soc. X, series*, 3).

According to Roxburgh the poisonous fruit is mixed up with rice and is employed to kill crows. It is used by the Hindus of Western India as an ear ornament for the idol Ganpatti, who is dressed up and seated in state in every Hindu house once a year, to bring good luck to the inmates (Dymock).

Occurrences

Assam	Dumpet, vern. Meejuren, Khasia and Jaintia hills, 13 Oct. 1900, Coll. D. Hooper ; Tangali Bam Garden, Joboca Oct. 1898, Coll. Dr. Prain's collector ; Mongsemdi May 1895 collected by the Reporter Economic Products to the Government of India, Jola Bastee near Teock Ghat, Jan. 1899, Dr. Prain's collector ; Shillong, Khasi Hills April 1902, Coll. H. G. Carter ; Haflong, N. Cachar, 2,500 ft. Coll. W. G. Crate ; Khasia, distributed at the Royal Garden, Kew, 1812-3, Griffith ; on the way to Keithemati 3,000 ft., Manipur (on the Eastern Frontier of India) February 4th 1882, Government demarcation Survey of 1881-1882, George Watt ; Sengamoi 3,000 ft. Manipur Coll. George Watt ; Sadiya, Kuwa bhatori, 25th Aug. 1909, Coll. I. H. Burkill.
Burma	S. Shan States Coll. Rev. R. W. MacGregor I.M.S. ; Keng Tung 5,000 ft. ; Shan States, May 1909, Coll. Capt. R. W. MacGregor ; Mogok, Upper Burma, Coll. W. H. Coopert Abdul Hoque, Upper Burma, September 1891, Coll. Abdul Hoque ; Peru Coll. S. Kurz., Madve hill, Upper Burma 20th February 1893, Coll. Dr. King's collector ; Fort Stedman Upper Burma 1893, Abdul Khalil ; Southern Shan States Indin, Upper Burma 1893, Abdul Khalil ; Kachin Hills, Upper Burma ; Dist. Mynela, Yunan Expedition 18th May 1868, Coll. D. J. Anderson ; Maymyo, Upper Burma, July 1858, Coll. Badal Khan ; 40 miles from Mandalay, July 1888, Dr. King's collector, Badal Khan Sujin, Upper Burma Aug. 1891, Coll. Abdul Huk.
Andaman	Narcondam 800 ft. ; Rangachang, S. Andaman, 16 Nov. 1889, Coll. David Prain.
Malay Peninsula . . .	Perak 500-800 ft., July 1886, Coll. Dr. King's Collector ; Batu Togoh, Perak 800 ft., Coll. L. Wray Jr. ; Perak, Coll. Revd. Father Scortechini ; Perak open mixed jungle, July 1883, Coll. Dr. King's collector Ulu Bubong ; Larut Perak-ching 500-800 ft., Sept. 1883, Coll. Dr. King's collector ; Malay Archipelago, 1,700 ft., 1881, Coll. H. O. Forbes ; Java, 5,000 ft., 1862.
Sikkim	Rishap 4,000 ft., Darjeeling, 28th July 1870, Coll. C. B. Clarke ; Rangno valley, Sikkim, 2,500 ft., June 1862, Coll. T. Anderson.
N. W. Himalaya	N. W. Himalaya, Coll. P. W. Mackinnon ; Dauglas Dub, 4,000 ft., Kumaon, August 1913, Coll. N. Gill ; Mussorie range, Coll. G. King ; Dehra Dun, June 1870, Coll. G. King.
Upper Gangetic Plain . .	Bharaich (Oudh), 22 June 1898, Coll. Kursukh ;
Central India	Ajmere, Ajmer-Merwar, Coll. M. C. Morr ; Guna, Gwalior, Coll. G. King.
Bengal	Royal Botanic Garden, Calcutta, August 1906 ; Agartala 500-600 ft., Tiperah 2nd January 1918, Coll. P. M. Debburman ; Magora, Jessore 30 June 1874, Coll. C. B. Clarke.

* O'Shaughnessy, W. B. (1841). Bengal Dispensatory P. 349

† Dymock (1885). *Veg. Materia Medica*, P. 345

Peninsular India . . .	Chodavaram, Rampa country, Godavari, 3 Oct. 1920 Coll. V. Narayanaswami; near Junjugudem, Godavari Dt. 5 Oct. 1920, Coll. V. Narayanaswami; Naduvanthumurhi, Travancore State 25 Aug. 1913, Coll. C. C. Calder and M. S. Ramaswami; Courtallum, Coll. M. Rama Rao; Komattiyeri, Javadi Hills 2,300 ft., S. India 28 Sep. 1916, Coll. C. E. C. Fischer; Mysore and Carnatic, Coll. C. Thomson; Kavalay Cochin 200 ft., Nov. 1910, Coll. A. Meebold; Bailur 3,800 ft., 22 Aug. 1905, Coll. G. S. Fisher; Verur Trav. Dec. 1910, Coll. A. Meebold; Kamalapore, Sept. 1910, Coll. A. Meebold; Perambicolam 3-4,000 ft., Cochin, Nov. 1910, Coll. A. Meebold.
Wall Cat.	Prome Hills, Wall Cat. 1826; Gongachora 20 May 1809.
Bihar	Singhbhum 9 June, 1903, Coll. H. H. Haines; Jatta Pagoda, Sundriban, Aug. 7, 1902, Coll. D. Prain.

17. ***Trichosanthes Lepiniana*** Cogn. Monogr. Phan. Vol. III, 1888, p. 377; leaves membranous, suborbicular, glabrous on both sides, smooth or slightly prickly and scabrous, broadly palmate 3-5-lobed, lobes broadly ovate or triangular, acute or shortly acuminate, margin sparingly subulate denticulate; tendril 3-4 fid; male racemes few flowered; bracts ovate, subulate-incised; calyx tube from apex to base narrow, dentate elongate, deeply 3-5-lobed; Involucraria Lepiniana Naud., in Hubr. Cat. 1868.

Stem robust, elongate, branched, furrowed, glabrous, smooth. Petiole stout, channeled, glabrous, often finely punctate-scabriculate, 4-6 cm. long. Leaves upper surface bright green lower surface pale green, base 5-nerved, 10-20 cm. long and often almost as broad as long, lobes divergent; indentations between the lobes broad, acute, base almost round 2-3 cm. deep. Tendril stout, elongate, furrowed, glabrous. Flowers dioecious. Common male peduncle robust, furrowed, glabrous, bearing 5-10 flowers at the top, 15-20 cm. long, bracteata at the base; bracts thin membranous, entire, narrowly oblong, base narrow, glabrous or puberulous, 2-3 cm. long. Pedicel erect ascending, thick, 2-5 mm. long; bracts, sparingly puberulous, many nerved, teeth long subulate, 4 cm. long, 2-3 cm. broad. Calyx tube, shortly puberulous, longitudinally channeled, 5-6 cm. long, apex 12-14 mm. broad, teeth erect, 14-16 mm. long, 5 mm. broad, lobes long subulate. Petals obovate 2-3 cm. long, deeply laciniate, lobations long fimbriate, filaments of the stamen thick, 2 mm. long; anther head 13-14 mm. long, 4 mm. thick. Female peduncles 2-4 cm. long, ovary oblong, glabrous. Fruit ovoid, smooth, red, 8 cm. long 6 cm. thick. Seeds black, margin obscure, apex truncate, base narrow, slightly wrinkled, 13-15 mm. long, 6-7 mm. broad, 2·5 mm. thick. Flowers April to June.

Habitat

Pondichery (J. Lepine in Herb. Mus. Par.); in Sikkim (Hook f. et. Thomson n. 14 in herb. Kew. Mus. Par. DC., Francav, Berol, Monac, Vindob., Flor. Ham).

Occurrence

Sikkim	Kolbong 3,000 ft., 9 June 1862, Coll. T. Anderson; Kurseong 3,000 ft., Darjeeling, 12 June 1870; Wood below Lebong 5,000 ft., 16 April 1857; Sikkim 1-4,000 ft., Coll. J. D. H.

18. ***Trichosanthes anaimlaiensis*** Bedd. in Madras Journ. Sc. (1864), Ser. III, I, 47; *T. Anamalayana,* Cogn. in DC. Monogr. Phan. 1881 III, p. 328;

Leaves 3-5 lobed, upper surface scabrous, lower pubescent, irregularly deeply serrate; tendrils 2-3 fids; male flowers in racemes, calyx male and female similar but lobes in the female are larger and widely laciniate, stamens 3, rarely 4, floral tube gibbose inserted, anthers jointed; female flowers axillary solitary either with a pair of lanceolata bracts or occasionally racemose, bracteate broadly laciniate with glands. Leaves 10-13 cm. long and as broad. Flowers white, corolla hirsute, fruit globose.

Habitat

In tropical India at Mt. Anaimalai, alt. 1,300 ft.

19. ***Trichosanthes himalensis*** C. B. Clarke in Hook. f. Fl. Brit. Ind. II, 608; *Trichosanthes cordata* Wall Cat. 6686 B; *Cucurbita filifolia* Wall Cat. 6721.

An extensive climber, with slender branching sulcate hairy stems; tendrils 3-fid. Petioles and leaves pubescent and hairy. Leaves about 5 in. diameter, nearly circular in outside, palmately 3-5 lobed, deeply cordate, irregularly serrate, roughish above, villous or pubescent beneath. Male peduncles 3-4 in., bracts $\frac{1}{2}$-$\frac{3}{4}$ in., narrowed to the base, not sheathing, lanceolate, incisoserrate. Calyx tube $1\frac{1}{2}$ in., very narrow, slightly hairy. Fruit 3-4 in., long, long cylindric, tapering at both ends. Seeds turgid, obovoid or drum shaped. Flowers April to September. *var. glabior:* leaves glabrous above, pubescent or scabrous on the nerves beneath. Khasia, 4,000 ft. Sikkim alt. 2,000-5,000 ft., from Yuksum to the plains.

Habitat

Sikkim, alt. 2,000-5,000 ft. from Yoksum to the plains, J. D. Hooker and C. B. Clarke.

Occurrence

Upper Gangetic Plain . . .	Kheri (Oudh), 11-4-98, Coll. Inyat.
Sikkim	Kalimpong 4-5,000 ft., Coll. Thomton Ripley; Mungpoo 3,000 ft., Darjeeling, Coll. C. B. Clarke; Sikkim 2,500 ft., Coll. G. King; Darjeeling 4,000 ft., Sept. 1881 Coll. G. S. Gamble; Pankhabari, Sept. 1875, Coll. G. King.
Assam	Khasia 4,000 ft., Coll. J. D. Hooker & T. Thomson.

20. ***Trichosanthes dicaelospermo*** C. B. Clarke in Hook. f. Fl. Brit. Ind. II, 609; *T. reniformis* Kurz. in J.A.S.B. 1871, **2,** 57

Plant, dioecious.

Stem long twining sulcate, puberulous. Leaves cordate-ovate acute denticulate softly shortly pubescent on both surfaces, 4 by $3\frac{1}{2}$ in. not at all lobed; petiole $1\frac{1}{2}$ in. densely villous. Male peduncles in pairs; bracts minute or 0. Calyx tube $1\frac{1}{2}$ in., narrow pubescent teeth spreading subulate. Fruit globose 1·5 in. in diameter, pubescent with 10 pale vertical bands. Seeds pale grey, embeded in orange pulp 3-celled, the lateral cells empty. According to Clarke this is perhaps Kurz's *reniformis* obtained in Sikkim Himalaya, but is not *T. reniformis* Miq. Fl. Ind. Bat. pt. i, 675, which has obtuse lobes to the leaves and the male spike leafy bracteate.

Flowers June to August.

Habitat

Sikkim 2,000-5,000 ft.; Khasi hills 4,000 ft.

Occurrence

Assam	Khasia 4,000 ft., Coll. J. D. Hooker & T. Thomson
Sikkim	Sikkim 1,800 ft. 2,000 ft. 14-6-1876, Coll. G. King; Sikkim 2-5,000 ft., Coll. J. D. Hooker; Sikkim, Coll. S. Kurz; Kurseong 28-8-57
N. W. Himalaya	Dehra Dun, Coll. G. King

21. ***Trichosanthes dioica*** Roxb. Fl. Ind. iii, 701; Wall Cat. 6692 A.B.D.

Vern. Sanskrit-*Patola, putulika;* Hind.—*Parvar, palval, palwal;* Beng.—*Patal*; Uriya—*Patal;* Pb.—*Palwal, Parmal;* Guj.—*Potala;* Tam.—*Kombu-pudalai;*

Dioecious plant. Stem creeping, running to a great extent, five sided, scabrous. Root perennial. Leaves alternate, petioled, cordate, dentate, scabrous, soft when young 3-4 in. in length. Petioles wooly, variously bent, channeled. Tendrils simple or two cleft. Male flowers axillary solitary or pretty long peduncles. Tube of the corolla very long trumpet like; stamens 3 distinct. Female flowers axillary, solitary short peduncled. Corolla large, with fringe. Fruit 2-$3\frac{1}{2}$ in. oblong obtuse on both ends, when ripe smooth and of a deep orange colour, about four inches long and the same in circumference. Seeds $\frac{3}{8}$ to $\frac{1}{2}$ in., half ellipsoid, compressed, corrugated on the margins. The unripe fruits and tender tops are much eaten by Indians as well as by Europeans and are reckoned exceedingly wholesome.

Flowers March to October.

Habitat

Throughout the plains of North India from the Punjab to Assam and East Bengal. It is extensively cultivated during the rainy season throughout the above mentioned localities, in the same way as the other gourds.

Medicinal and other uses

The leaves, the fresh juice of the fruit and the root are all used medicinally. The leaves are described as a good light and agreeable bitter tonic. The tender tops are regarded as tonic and febrifuge. The fresh juice of the unripe fruit is often used as a cooling and laxative adjunct to alternative medicines. The root is classified amongst the purgatives by *Susruta*.* In bilious fever a decoction of the leaves and coriander in equal parts is given as a febrifuge and laxative. The juice of the leaf is recommended by some eminent physicians as a remedial application to bald patches†. An alcoholic extract of the unripe fruit is said to be a powerful and safe cathartic. According to Ray Bahadur Kanny Lal De‡ the bulbous part of the root is a hydragogue cathartic, operating in the same way as Elaterium, for which it can be substituted. He describes the plant as a wholesome bitter and useful tonic. Dr. Bowser§ from his personal experience describes it as a febrifuge and tonic. The Hindu physicians of the old school placed much confidence in it in the treatment of leprosy. 'The leaves of patal are bitter and produces tonic properties. They are generally fried with flower paste in ghee and eaten. The fruit is an excellent vegetable, which agrees well with convalescents, even from bowel complaints. It is largely consumed as food. The conserve of the fruit is also a nice food for convalescents and can easily be prepared' (Surgeon R. L. Dutt,). "The root is a drastic purgative useful in dropsy" (Assistant Surgeon S. C. Bhattacharjee, Chanda).

The fruit is oblong green when young and orange or yellow when ripe. Unripe fruit is much esteemed as a vegetable, being considered very wholesome and especially suited for patients recovering from illness. The tender tops are also eaten as a pot herb.

Occurrence

Assam	Teock Ghat, near Tangali Bam. Oct. 1898, Dr. Prain's collector; Khasia, Coll. Griffith; Khasia hills 2-3,000 ft. November 1877; Banks of Kullung, October 1847; Orang jungle, March 1902, Coll. A. C. Chatterjee, Assam, February 1891, Coll. Dr. King's collector; Lowkwa 250, Nowgong 26 March, 1885.
Bengal	Agartala 500-800 ft. Hill Tipperah; 20 October 1915, Coll. P.M. Debbarman; Western Bengal, Coll. S. Kurz; Faridpur Station, 31st July 1868; Botanic Garden, Calcutta.
Bihar	Dalsing Sarai, Darbhanga, August 1900, Dr. Prain's collector, Karagola, Purnea, 28th August 1877, Coll. G. King.
Gangetic Plain	Cultivated, Jaunpur, early part of 1916, Coll. G. O. Allen.
Upper Gangetic Plain . .	Pilibhit 2-6-98, Inayat; Koemari, Saharanpur, 12th April 1808, April 1881.
N. W. Himalaya	Silla Garo to Chamba, 4-6,000 ft., Chamba State, October 1896, Coll. J. H. Lace, Ladak.
Wall Cat.	Sylhet, Coll. W. Gomez, 6692 C.

22. ***Trichosanthes integrifolia*** Kurz. in Jour. Asiatic Soc. Bengal (1877) xlvi II, 99; *Gymnopetalum integrifolium* Kurz. in flora 1871, 295; *Cucumis integrifolius* Roxb. Fl. Ind. III, 724; Wall. Cat. 6730, *Trichosanthes officinalis* Wall. Cat. 6694.

A twining herb; stem scabrid; tendrils usually simple or 2 fid. Leaves cordate-ovate nearly entire, 2 in. in diameter, very harshly scabrous above, densely villous beneath, margin undulate scarcely denticulate; petiole 1 in. Flowers monoecious all solitary white; male peduncle solitary without bracts $1\frac{1}{2}$ in. female peduncle $\frac{1}{4}$ in. *Male*: calyx-tube elongate, densely brown-villous, teeth 5, lanceolate; corolla divided nearly to the base, lobes obovate, entire, yellow veined, pubescent.

* L. Bhisagratna, K. L. (1905). *Susruta Samhita*, (Eng. Trans.), 400-417
† Dutta, U. C., (1900). *Materia Medica of the Hindus*, 169-313
‡ Dey, K. L. (1896). *Indigenous Drugs of India*, 96
§ Bowser (1893). In Watt's *Dictionary of Economic Products* 6, (4), 83

Female: calyx and corolla as in the male; stigma 3, oblong. Fruit $\frac{5}{8}$-$\frac{3}{4}$ in. diameter, orange red glabrous smooth.

Habitat

Bengal (Roxburgh), Poulong (Irrawady estuary), Wallich.

23. ***Trichosanthes Thwaitesii*** Cogn. in DC. Mong. Phan. iii, 387. Syn. *Trichosanthes integrifolia* Thwaites Enum. Pl. Zeyl. 127, not of Kurz.

An annual, dioecious. Leaves $2\frac{1}{2}$-6 by $1\frac{1}{4}$-2 in. glabrous nerved, elliptic or ovate acuminate less often lanceolate, 3-nerved entire coriaceous base rounded or cordate, petioles 3 in. tendrils simple. Flowers somewhat large solitary. Fruit spherical shortly apiculate, 3 in. diam., red; seeds $\frac{1}{2}$ in. numerous crowded, smooth oblong, oblique, compressed truncate at the hilum, with two indentations at the vertex, testa blackish green.

The species is described in Fl. Br. Ind. as *T. integrifolia* and the author confessed that he did not seen the specimens. There is also no specimen up till now available in the Sibpur Herbarium. It may be a doubtful species.

Habitat

Ceylon, 2,000-4,000 ft., Thwaites.

3. Gymnopetalum

Gymnopetalum, Arn. in Hook, Journ. of Bot. (1841) 3, p. 278; Wight in Ann. and Mag. of nat. Hist. 8, p. 270; Endl. Gen. pl. suppl. 2, p. 77; Meisn. Gen. comment. p. 356; Roem. Syn. fasc. 2, p. 17; Miq. Fl. Ind. Bat. 1, part 1, p. 679 (Oart.); Benth et Hook. Gen. pl. 1, p. 822; Kurz. in Journ. Asiat. Soc. Beng. 40, part 2, p. 57 et v. 46, part 2, p. 99; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 611.—*Tripodanthera* Roem. Syn. (1846) facs. 2, p. 11, 48.—*Scotanthus* Naud. in Ann. sc. nat. ser. (1862) 4, v. 16, p. 172; Benth et Hook. 1.c.p. 822.—Bryoniæ, Momordiceæ et Cucumeris spec. auct.

Climbing herbs; tendrils usually simple or 2-fid. Leaves petioled, 5-angled or deeply 5-lobed; flowers white rather large dioecious or occasionally monœcious; male peduncles in mature plants 2 from the axil, the earlier 1—flowered, the later longer racemose, one or other often suppressed; bracts of racemed flowers large, incised or small lanceolate; females 1-flowered usually in separate axils. *Male*: calyx tube long, contracted near the mouth, limb of 5 lanceolate segments; petals 5, not fimbriate on margin; stamens 3; anthers included connate, elongate one 1-celled, two 2-celled; cells complicate. Rudiments of the ovary represented by 1 or 3 small linear processes. *Female*: calyx and corolla as in the male; ovary oblong; style long, stigmas 3, short linear, acute at both ends. Seeds many or few ellipsoid, compressed, margined, nearly smooth. Distrib. Five species are distributed in India, China and Malay Peninsula. Species 7.

Key to the Species

A. Bracts of the male racemes prominent narrowed at the base deeply lacerate at apex	1. *G. cochinchinense*
B. Bracts of the male racemes oblong serrate	2. *G. quinquelobum*
C. Bracts of the male racemes simple small linear	3. *G. Wightii*

1. ***Gymnopetalum cochinchinenses*** Kurz. in Jour. As. Soc. Beng. (1871) xl. II, 57; *Bryonia cochinchinensis*, Lour. Fl. Cochinch, 595; DC. Prodr. III. 305; *Momordica tubiflora* Roxb. Fl. Ind. iii, 711 not of Wallich; *Tripodanthera cochinchinensis* Roem. Synops. ii, 48; *Scotanthus tubiflorus* Naud. in Ann. Sc. Nat. Ser. 4 XVI, 172, t. 3; *Trichosanthes cucumerina* Wall Cat. 6690 E; T. Fatoa Ham. in Wall Cat. 6695; *Bryonia grandis* Wall Cat. 6700 KL.

A slender climber, stem 5-angular, more or less scabrous hairy. Leaves 5-angled or lobed about half way down; 2-3 in. diameter, scabrous on both surfaces; tendrils simple or 2-fid. Bracts to the male racemes prominent narrowed at the base deeply lacerate at the apex. Male recemed peduncle sometimes 6-8 in., usually shorter; bracts $\frac{3}{4}$ in., incise-serrate, lobes often again incised. Calyx

tube $\frac{3}{8}$ in., villous, closed by deflexed hairs within above the stamens. Rudiment of the ovary in the male flower 3. Petals $\frac{1}{2}$ in., ovate entire or somewhat crenate. Fruit 2 by $\frac{3}{4}$ in., orange-red, somewhat scabrous, with 10 longitudinal ribs, pulp greenish, not very succulent. Seeds $\frac{1}{4}$ by $\frac{1}{2}$ and $\frac{1}{20}$ in. thick.

Flowers August to November.

Habitat

Sikkim up to an elevation of 2,000 ft. Assam, Cachar, Bengal, common. Chota Nagpur. Tenasserim. Distributed to Malaya and China.

Occurrence

Bengal	Sibpur, 29-9-21, Coll. P. M. Debburman; Barodi, Dacca 1 Sept. 1871 Coll. C. B. Clarke; Matita, Dacca 31 Aug. 1868, Coll. C. B. Clarke.
Wall Cat.	Rangoon 14 Aug. 1826, 6700 L; Goalpara 29 Aug. 1808 Gongachera 29 May 1809.
Bihar	Singhbhum 1 Oct. 1902— Coll. H. H. Hains.
Sikkim	N. Bengal, Sikkim Terai, between Goreedora and Kuprail in jungle 30-9-68.
Bengal	Agartala, 600-800, Hill Tipperah, 11th Nov. 31st December 1915, Coll. P. M. Debbarman.
Assam	Makum, Abor Expedition, 21-11-1911, Coll. I. H. Burkill; Haflong 2,675 ft. 10 Aug. 1908, N. Cachar Coll. W. G. Craib; Tangali Bam., Jaboca, 3 Aug. 1898, Coll. Dr. Prain's collector; Theria, Khasia 250 ft., 10 Oct. 1886 Coll. C. B. Clarke.
Burma	King Tung, 2,500 ft., S. Shan States, July 1909, Coll. Capt. R. W. McGregor; Arracan, Akyab Coll. S. Kurz; Baptaughar—Coll. Dr. Melelland; Tennasserim, Coll. Helfer; Kachim Hills, Upper Burma, 1897, Shaik Mokim; King Tung 400 ft., S. Shan States, December 1909, Coll. Capt. R. W. McGregor.
Bengal	Kodala Hill, 30 miles from Chittagong, Chittagong hill tract, September 1886, Coll. Dr. King's collector; Chittagong October 1869, Coll. S. Kurz.; Chittagong, November 1898, Coll. Mokim.
Sikkim	Chooyoung, 1901, Dr. Prain's collector; Renchy to Rimchinpong 2-5,000 ft., 1 Nov. 1862, Coll. G. King; Rungeet & Teesta junction November 1875, Coll. G. King.
Peninsula India	Veligonda hills Block B, Nellore Dist., 28th July 1914, Coll. M. S. Ramaswami.
Malay Peninsula	Langkano, Kedah, Sept. 1890, Coll. C. Curtis; Pekan, Pahang, 1891, Coll. H. K. Ring; Perak 400-600 ft., July 1886, Coll. King's collector. Sumatra 12 Aug. 1879; Lampung, Sumatra 12 Aug. 80, Coll. H. O. Forbes;

2. ***Gymnopetalum quinquelobum*** Miq. Fl. Ind. Bat. i. pt. i. 681; *G. heterophyllum* Kurz. in Trimen Journ. Bot. 1875, p. 326; *Scotanthus Porteanus* Naud. in Ann. Sc. Nat. Ser. 5, v. 25.

This species approaches nearer to *G. cochinchinensis*. Leaves suborbicular deeply 5-lobed lobes often 3 fid or subpinnatifid, narrow, subsinuate. Bracts of the male racemes oblong serrate. Kurz's *G. heterophyllum* agrees as described in the present species; it is perhaps a specimen with poorly developed male racemes. Kurz says the flowers is white, and quotes *Bryonia heterophylla* Wall. Cat. 6711, which obscures the whole matter, for that plant is *Bryonia palmata* wall (now *Coccina*) while *B. heterophylla* Wall No. 6704 (and of which there is a solitary sheet) differs altogether from Mr. Kurz's description and is a *Ceraciocarpum*.

Flowers November to April.

Habitat

Burma—Rangoon; Mr. Clellard. Pinang; Portar.

Occurrence

Malay Peninsula	Griffith. Singapore; G. Thomson Distb. Malaya and Borneo, Malacca Hill, 1892.
Java	Bantaun Dec. 1879, Coll. H. O. Forbes; Java Coll. T. Horsfield W. Java 1-3,000 ft.; G. Gantur, Java 1-4,000 ft., 1861, T. Anderson.

Andamans	Mt. Hurriel, Nov. 1889, Coll. David Prain; Pt. Monat, S. Andaman, Coll. S. Kurz; Kamorta Nicobar Isls., February 1875, Coll. S. Kurz.
Upper Gan. Plain . . .	Banda N.W.P., Indrayan, Aug. 1902, Coll. Mrs. A. S. Bell; Kheri (Oudh). 21 Aug. 48, Coll. Inyat
N. W. Himalaya . . .	Dehra Dun 12 Sept. 1870, Coll. G. King:
Burma	Moulmain, 10 Feb. 29; Silehmyo, 1 Feb. 68, J. Anderson.

3. ***Gymnopetalum Wightii*** Arn., in Hook J. Bot. iii (1841) 278. *G. zeylanicum* Arn. l.c.; *Bryonia tubiflora* W. & A. Prodr. 347; *Cucurbita umbellata* Wall Cat. 6724.

Leaves 5 angled or lobed, 2 in. in diameter, more or less pubescent on both surfaces, denticulate, lobes acute or obtuse or 0; petiole 1 inch. Male racemose, peduncle 2 in.; flowers crowded, sub-umbellate; bracts $\frac{1}{4}$ in. linear, pedicles often $\frac{1}{4}$ in.; peduncles of the female flowers $\frac{3}{8}$ in. Calyx tube $\frac{1}{2}$ in., slender with scattered hairs or very pilose, lobes, lobes small. Petals $\frac{1}{4}$ in. (yellow according to Arnott & Hook., white according to Thwaites). Rudiment of the ovary in the male flower simple. Fruit $1\frac{1}{2}$-in. more or less hairy, not ribbed. Seeds $\frac{1}{2}$ by $\frac{1}{2}$ in. without corogations or angles.

Flowers October to January.

Habitat

South Deccan Peninsula, Wight; Canara, Hohenacker No. 622. Ceylon, ascending to 5,000 ft., Walker, Gardner, Thwaites.

Occurrence

Peninsular India	Kavelay Cochin, 2,000 ft., Nov. 1910, Coll. A. Meebols; Karimalai, S. Malabar 4,500 ft., 12 Jan. 1910, Coll. C.E.C. Fischer; Maliyamaduyam 4,000 ft. 11 Sep. 1905, Coll. C. E. C. Fischer; Madras.
Ceylon	Central Province, up to an elevation of 5,000 ft., Coll. Thwaites.

4. Biswarea

Biswarea Cong. in Comptes-rend. Soc. Bot. Belg. (1882, xxi), 16; *Warea* of C.B. Clarke in J. Linn. Soc., 1876, xv, 127.

Extensively scandent herb, tendrils 2 or 3 fid, long petioled, ovate or deeply 5-lobed. Flowers large, yellow, dioecious; males frequently with two peduncles from one axil, one early deciduous 1-flowered the other bearing a raceme without bracts; females solitary or with long peduncles. *Male*: calyx tube cylindric, narrow, then suddenly widened campanulate, subhemispheric, teeth 5 linear; petals 5, ovate nearly separate, entire; stamens 3; anthers connate, included, one 1-celled, two 2-celled, cells conduplicate. *Female*: Calyx and corolla as in the male; ovary oblong; style long with 3 wide stigmatic lobes; ovules horizontal, many, placentas 3, vertical. Fruit oblong, attenuate at both ends, 3-angular, 6-ribbed, 3-valved, usually to the base. Seeds in each cell about 16, in two rows, horizontal, compressed, ellipsoid, smooth. Differs from *Gymnopetalum* by the large campanulate mouth to the calyx; by the divided tendrils, and the anthers extend from the tubular portion of the calyx.

Biswarea tonglensis Cong. l.c. *Warea tonglensis* C. B. Clarke in Jour. Linn. Soc. xv 129; *Gymnopetalum* sp. No. 6, Herb. Ind. or, H. f. & T.

Stem and peduncle nearly glabrous. Leaves 6-9 by 4-5 in., polymorphous, cordate denticulate, nearly glabrous ovate acute or 5 lobed or cut nearly to the base into narrow segments; petioles 4 in. Male peduncles 8 in.; pedicles $\frac{1}{2}$-$\frac{3}{4}$ in. calyx tube $1\frac{1}{2}$-in. pubescent, cylindric portion more than $\frac{3}{4}$ in. Petals $\frac{3}{4}$ in. Fruit 4 by $1\frac{1}{2}$-in. included in Herpetospermum by J. Hooker in Gen. Pl. i, 839.

Flowers August to October.

Habitat

Sikkim, Alt. 6-1,000 ft., very common; h.f.j.d.h.; Tonglo N., C. B. Clarke.

Occurrence

N. W. Himalaya . . . . Tranda, Coll. Dr. Stoliczka.
Sikkim . . . . . . Senchal, Coll. S. Kurz ; above Phadonchen 7-1,000 ft. 19 Aug. 1910, Coll. W. W. Smith ; Rungbie 6,000 ft. 21 July 1870 ; Senchal 8,000 ft. Darjeeling 13th June, Coll. C. B. Clarke ; Tangloo 8,500 ft. 8 Oct. 75, Coll. W. Gamble ; Sikkim 8-10,000 ft. Coll. J. D. Hooker ; Tangloo 9,000 ft. Darjeeling 13th Sept. 1875 ; Darjeeling, 8,500 ft., 3rd Sept., 1875, Coll. C. B. Clarke ; Sikkim Coll. G. King.

5. Lagenaria

Lagenaria Ser. in Mem. Soc. Phys. Genev. (1825) iii, 1. 25 t. 2, et in DC., Prodr., **3**, p. 299 ; W. et Arn. Prodr., 1, p. 341 ; Spach. Veg. phan., 6, p. 194 ; Meisn. Gen., p. 127 (91) ; Endl. Gen. p. 938 ; Torr. et Gr. Fl. N. Amer., 1, p. 543 ; Roem. Syn., fasc. 2. p. 13, 60 ; Miq. Fl. Ind. Bat., 1, pars 1, p. 668 ; Naud. in Ann. sc. nat ser. 4, v. **12**, p. 91 ; Harv. et Sond. Fl. Cap., **2**, p. 489 ; Benth. Fl. Austral, 3, p. 315 ; Benth et Hook. Gen., 1, p. 823 ; Hoof. in Oliv. Fl. trop. Afr., 2, p. 529 ; Cogn. in Mart. Fl. Bras., fasc. 78, p. 7 ; Clarke in Hook. f. Fl. Brit. Ind., 2, p. 613.—Cucurbita Tourn. Instit., p. 107 ; Adans. Fam., 2, p. 138.

Large climbing herbs, tendrils 2-fid ; leaves ovate or orbicular, cordate, dentate ; leaf teeth glandular ; petiole long, with 2 glands near its apex. Flowers large, white, solitary, monoecious or dioecious ; males with long and females with short peduncles. Sepals 5, connate in a funnel shaped or subcampanulate tube ; lobes of timb narrow. Petals 5, obovate free. *Male* : stamens 3 ; anthers connate included, one 1-celled, two 2-celled, cells conduplicate. *Female* : carpels 3, connate in an oblong, 1 celled ovary ; ovules many, horizontal, in 3 vertical placentas ; style short, with 2-fid, stigmatic lobes. Fruit a large, thickly coriaceous or almost woody polymorphous berry, usually broader upwards. Seeds numerous, horizontal, smooth, with marginal groove.

Lagenario vulgaris Seringe. im Mem. Soc. Phys. Genev. iii, 1 (1825), 23 ; *L. vittata, hispida* and *idolatrica* Seringe l.c. 299 ; *Cucurbita Lagenaria* Linn. ; Lamk. III. t. 795 ; Roxb. Fl. Ind. iii, 718 ; Wall Cat. 6719—Rheede Hort. Mal. viii t. 5.

The Bottle gourd. Vern. Sans. *Alabu* (cultivated form), *kutumbi* (wild form) ; Hind. *Kaddu, alkaddu, golkoddu, lauki, ghia, lauka, lau* (cultivated form), *tumri, titalau* (wild form) ; Beng. *lau* (cultivated form), *tita lau* (wild form) ; Santal. *Kadu* ; Nepal. *Phasi, kondra ;* Pb. *Kaddu, lauki ;* Tam. *Soriai-kai, Shora kai ;* Tel. *Kundanunga ampa-chettu.*

An annual, climber with velvety hairs throughout, tendrils 2-fid, stems stout, 5-angled, leaves up to 6 in., ovate or round, 5-angular or lobed leaf teeth glandular base notched, toothed, stalk long with 2 glands at the apex ; flowers 2-4 in. diam., white, solitary, male and female on the same or different plants, male flowers on stalks 1-6 in. long, female on stalks 1 in. long. Some flowers are apparently with abortive ovary.

Male flowers : Calyx tube ½ in. long, funnel shapped, velvety, teeth 5, narrow, petals 5, 1-2 in. long, hairy on both sides, crumpled ovate with a broad tip, stamens 3, anthers joined, enclosed. *Female flowers* : calyx and corolla as in the male. Style short with 3-fid, stigmatic lobes ; fruit up to 6 ft. in length, round, or bottle shapped, thick, almost woody when ripe, seeds $\frac{3}{4}$ by $\frac{3}{8}$ in., $\frac{1}{8}$ in. thick, with a grove parallel to and near the margin, white. Petioles—number of bundles 10, hollow at the base and solid at the end with a vascular strand running through the hollow tubular petiole.

Flowers December to April.

Habitat

Extensively cultivated throughout India and in many parts of Australia, America and China ; sometimes also found in wild state in some parts of India, the Moluccas and Abyssinia.

Medicinal and other uses

The seeds were originally one of the four old Cucurbitaceous seeds of the ancients but pumpkin seeds are now generally substituted for them (Dymock).* They are considered cooling and are

* *Materia Medica West. India* 1855, 2nd Ed. 349

given internally as a remedy for headache. The oil from the seed is externally employed in headache. The pulp of the wild form (tumri) is purgative, sometimes it acts as a strong purgative. Lindley states that certain sailors were poisoned by beer which had been standing in a hollowed bottle gourd, the symptoms produced being similar to those attending cholera. It is said to be largely used by the lower class people in the Punjab, as a purgative for horses. The pulp of the cultivated form is occasionally employed as an adjunct to purgatives, and is also considered cooling, diuretic, antibilious, useful in coughs and as an antidote to certain poisons. It is applied externally as a poultice and as a cooling application to the shaved head in dilirium. The leaves are purgative, and are recommended by Hindu physicians to be taken in the form of decoction for jaundice. The juice of the leaf is given for children's diarrhœa.

The cultivated forms are eaten both by Indians and Europeans. The latter boils the young fruit and take as vegetable marrow. If hanged in a free current of air it will keep well for three or four months, hence it may be used as a vegetable for sea voyages. The young shoots and leaves are also considered good vegetable by the Indians.

Economic use: The dried shell of the fruit of the bottle shaped gourd is used as a bottle for water and by the Nagas for holding their zu or beer. The small wild form tumri is used for making string instruments like sitar and bina. The latter instrument is principally used by snake charmers. In Deccan and other localities, the hollowed-out gourd is used as a float for crossing rivers, four or five being considered sufficient to support a man.

Occurrence

Sikkim	**Kalijhora 1,000 ft. 11 Dec. 15, Coll. G. H. Cave; Great Ranjiet valley, Coll. S. Kurz.**
Bengal	**Thana Makua, Sibpur, 9th May 1916; Agartala 500-800 ft., Hill Tipperah, Coll. P. M. Debbarman.**
Peninsular India	**Madras; Sind 27th January 1896; Bombay.**
Upper Gangetic Plain . .	**Banda, U. P. 19th May 1903, Coll. Mrs. A. S. Bell.**
N. W. Himalaya	**Soa valley 4-5,000 ft., Sept. 1895, Coll. J. H. Lace.**
Andamans	**Ranga chang, April 1891, Coll. Dr. Prain; Manpur, S. Andaman 13-12-1892, Coll. Dr. King's collector.**
Bihar	**Chota Nagpur, 24 Aug. 75, Coll. J. T. Wood.**
Assam	**Mangaldai, March 1902, Coll. A. C. Chatterjee; Margherata, February 1902 Coll. A. C. Chatterjee.**
Burma	**Pegu, Irrawaddy and Sittang valley, Prome, Coll. S. Kurz.**
Assam	**Kohima in the Naga hills, Manipur 3-6,000 ft., April to August 1892; Katcha, February 1875, Coll. S. Kurz.**

6. Herpetospermum

Herpetospermum Wall Cat. n. 6761 (1831) Hook f. in Benth. and Hook. Gen. Pl., **1,** p. 834; C. B. Clarke in Hook. f. Fl. Brit. Ind., **2,** p. 613; *Rampinia,* C. B. Clarke in Journ. Linn. Soc. 1876, **15,** p. 129; Bryoniæ spec. Auct.

Extensively scandent, tendrils 2-3-fid. Leaves long petioled, cordate, ovate, little lobed. Flowers large, yellow, dioecious; males frequently with two peduncles from one axil, one early deciduous 1-flowered, the other racemose without bracts females solitary on very short peduncles. *Male*: calyx-tube elongate, cylindric at the base, above narrow funnel shaped; teeth 1-5, long included, one 1-celled, two 2-celled, cells conduplicate. *Female*: calyx and corolla as in the male; ovary oblong, 3-celled, style long, with three oblong bifid stigmatic lobes; ovules pendulous, 4-6 in each cell. Fruit broad-oblong, narrowed at both ends, 3-angular, irregularly sinuate-costate, valves three separating from the axis nearly to be base. Seeds in two rows in each cells, flat, oblong, pendulous, the lower end corrugate or almost 3-lobed.

Herpetospermum caudigerum Wall. Cat. n. 6761; *Bryonia pendunculosa* Seringe in DC. Prodr. iii, 306; *Rampinia herpetospermoides* C. B. Clarke in Journ. Linn. Soc. xv, 130.

Stem and peduncles more or less pubescent. Leaves 3-6 in. long and broad, usually pubescent on both surfaces. Serrate acuminate; petiole 2-4 in. *Male* peduncle 8 in., pedicles 1 in., hairy. Calyx tube 1 in., pubescent outside. Petals often 1 in. Rudiment of the ovary in the male linear, simple. Fruit 3 by $1\frac{1}{2}$ in., more or less pubescent. Seeds usually 12, sometimes 18, $\frac{1}{2}$ by $\frac{1}{4}$ and $\frac{1}{8}$ in.

thick, often exhibiting when dried wavy marks on the surface, packed in a fibrous almost juiceless pulp. Wallich's Khasi specimen exhibits ripe seeds which are very narrow, incised at the lower end so that the middle lobe appears as a spinous tooth. Lady Dalhousie's collections of specimens at Simla are nearly glabrous with smaller flowers. *Herpetospermum* of Benth. and Hook. f. Gen. Pl. i. 834, described from imperfect materials included *H. caudigerum*, *Warea tonglensis* and *Edgaria darjeelingensis*. The generic character did not fit *Warea* or *Edgaria* and required emendations to the ovules and seeds of Wallich's *Herpetospermum*.

Flowers August to September.

Habitat

Temperate Himalaya, from Simla and Kumaon to Bhotan, alt. 5,000-8,000 ft.; very common in Sikkim, Khasia Mts.; Wallich.

Occurrence

N. W. Himalaya . . . . Alwar to Baira 4-6,000 ft., Chamba State, 30th Sept. 1898, Coll. J. H. Lace; Dehra Dun 1870, G. King; Simla.

Sikkim . . . . . . Cheung Chang, 6,000 ft., Coll. Ribu and Rhomoo; Garden of Lasha house, Tibet frontier commission 1904, Coll. H. J. Walson; Sinchal 8,000 ft., Darjeeling, 15th Sept. 1876, Coll. C. B. Clarke; Sikkim, S. Kurz; Sikkim, 7-9,000 ft., Coll. J. D. H.; Lachung 9,000 ft., 27 Aug. 92, Coll. G. A. Gammie; Kaljoriníe, 10,000 ft., Aug. 1888—Coll. D. Ging's collector; Yoümtham 190 Dr. Prain's collector.

7. Luffa

Luffa, Tourn. Act. Acad. Paris, 1706, p. 84, tab. 6; Dill. Nov. Gen. p. 156; tab. 11; Adans. Fam. **2**, p. 138; Cavan. Icon. **1**, p. 7, tab. 9, 10; Vent. Tabl. **3**, p. 513; Willd. Spec. **4**, p. 380; Poir. in Dict. sc. nat. 27, p. 287; Bl. Bijdr. p. 922; Ser. in DC. Prodr. 3, p. 302; W. et Arn. Prodr. 1, p. 343; Roxb. Fl. Ind. **3**, p. 712; Spach, Veg. phan. **6**, p. 217; Meisn. Gen. p. 126; (91); Endl. Gen. p. 937; Arn. in Hook. Journ. of Bot. **3**, p. 277; Wight in Ann. and Mag. Nat. Hist. **8**, p. 269; Roem. Syn. fasc. **2**, p. 14, 63; Miq. Fl. Ind. Bat. 1, part. 1, p. 665; Naud. in Ann. sc. nat. ser. 4, v. **12**, p. 118; Harv. et Sond. Fl. Cap. **2**, p. 530; Benth. Fl. Austral., **3**, p. 316; Benth. et Hook. Gen. 1, p. 823; Hook. f. in Oliv. Fl. trop. Afr. **2**, p. 530; Cogn. in Mart. Fl. Bras. fasc. **78**, p. 9; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 614;—Turia Forsk. Fl. Aegpt. Arab. p. 165 (1775); Poir. in Lam. Encycl. meth. Bot. **8**, p. 139, et in Dict. sc. nat. **56**, p. 124; Ser. in DC. Prodr. 3, p. 303, Meisn. Gen. p. 127 (92);—Trevouxia Scop. Introd. p. 152 (1777); Juss. in Dict. sc. nat. **55**, p. 180. Poppya Roem. Syn. fasc. **2**, p. 13, 59 (non Neck).—Momordicæ, Cucurbitæ et Cucumeris sp. auct.

Annual herbs. Tendrils 2-many fid. Leaves 5-7 lobed (rarely subentire) with glands in rows on the lower surface of the leaf especially on both sides of the prominent veins; petiole without glands at the apex. Flowers monœcious (rarely diœcious), rather large, yellow or white, males and females often from the same axil. Male flowers racemose. Calyx tube campanulate or turbinate; lobes 5, triangular or lanceolate. Petals 5 free, spreading, obovate or obcordate. Stamens 3 (rarely 5), inserted on the calyx tube; filaments free or connate; anthers exerted, free, one 1-celled, the others 2-celled, the cells sigmoid, often on the margin of a broad connective. Rudimentary ovary glanduliform or o. Female flowers solitary. Calyx tube produced beyond the ovary; corolla as in the male. Staminodes usually 3, thick. Ovary elongate, sulcate angled or cylindric, 3-placentiferous; ovules numerous, horizontal; style columnar; stigma 3-lobed. Fruit dry, oblong, or cylindric (not spherical), acutely ribbed or terete, smooth or echinate, fibrous in the 3-celled, terminated by the persistent style, usually circumscissis near the apex. Seeds many oblong, compressed.

Species 10, in the tropical regions of the old world one species indigenous in America.

KEY TO THE SPECIES

A. Stamens 5
  B. Male pedicles clustered in the axil . . . . 1. *L. graveolens*
  BB. Male flowers racemed on long peduncles . . . . 2. *L. cylindrica*
AA. Stamens 3
  B. fruit angled
    C. Fruit elongate 10 angled, covered by spines or papillae . . . 3. *L. acutangula*
  BB. Fruit not angled
    C. Fruit elliptic, densely covered with bristles, filaments united . . 4. *L. echinata*
    CC. Young fruit spinous, spines densely wooly filaments free . . 5. *L. umbellata*

1. ***Luffa graveolens*** Roxb. Hort. Beng. 70 ; Wall. Cat. 6752 ; Naud in Ann. Sc. Nat. Ser. 4, xii, 124 ; Kurz. in Journ. As. Soc. 1877, pt. ii, 101.

Stems slightly villous, tendrils from three to four cleft. Leaves reniform, somewhat lobed, and always toothed, axillary, punctuate. Scabrous above, pubescent on the nerves beneath ; petiole 2-3 in. Male pedicles few, much shorter than the petiole. Petals 5, $\frac{1}{4}$ in., yellow entire ; stamens 5. Female peduncle short, sometimes divided with 2-3 flowers each pedicel carrying a small ovate entire thick bract $\frac{1}{8}$ in. Fruit 2 by 1 in., covered with pepillæ. Seeds scarcely $\frac{1}{4}$ in., very many, packed in fibres, smooth not margined.

Flowers August to September.

Habitat

Sikkim 1,000-2,000 ft. ; J.D.H., Rajmahal hills ; Roxburgh. Plains of East Bengal ; C.B. Clarke. Chittagong, Kurz., Distrib. North Australia. A native of the Rajmahal hills, from thence the seeds were brought to Botanic Garden, Calcutta, where the plants blossomed during the rainy season and the seeds ripened about three months afterwards.

Occurrence

Sikkim	Sikkim Terai, N. Bengal, Kuprail, Sept. 1868, Coll. S. Kurz
Bihar	Chota Nagpur 24·875, Coll. J. J. Wood ; Jatta Pagoda, Sundribans, 7th Aug. 1902, Coll. Dr. Prain ;

2. ***Luffa cylindrica*** (Lour) Roem. *Syn. Pepon.* 63 ; Naud. in Ann. Sc. Nat. Ser. 9, xii, p. 119 ; Kurz. in Journ. B. Soc. 1877, pt. ii, 100 ; Sampson in Kew Bull. Ser. 12, 1936, p. 106 ; *Luffa ægyptiaca* Mill. Gard. Dict. ed. viii ; DC. Prodr. iii, 303 ; *L. pentendra* Roxb. Fl. Ind. iii, 712 ; W. & A. Prodr. 393 ; Wall. Cat. 6751 ; Wight Ic.t. 9999 ; *L. racemosa* Roxb. l.c. 715 ; *L. clavata* Roxb. Hort. Beng. 104. Fl. Ind. iii, 714 ; *L. acutangula* W. & A. l.c. not Roxb. *L. Petola* and *Cattupicinna* Seringe in DC. l.c. ; *L. Parvala* Wall. Cat. 6758 ; *L. Gosa, hederacea and Satpatia* Wall. Cat. 6753, 6755, 6757 ; *Bryonia cheriophylla* Wall. Cat. 6715 A ; *Momordica Luffa* Linn.

Vern. Hind. *Ghia tarui, purula ;* Beng. *Dhun-dul, dhumdul ;* Assam. *Bhol, bhatkerela, bhatkakrel ;* Nepal. *palo ;* N.W.F. *Ghiya toroi, Ghiya tori ;* Kumaun. *Tarod, ghiya taroi, turai, dhandal ;* Pb. *Ghia tori, ghi turai, ghi gandoli ;* Sind. *Turi, liasada ;* C.P. *Dilpasand, teldoaka ;* Bomb. *Ghosal, parosi, parula, turi, gonsali ;* Gurz. *Turia ;* Tel. *Cuttibera, netibera, munebira ;* Burma. *Thabwot, tha pwot-kna ;* Sing. *Neyang-nuttucolu ;* Sans. *Rajakostrataki ; dirghapatolika ;* Arab. *Luff ;* Pers. *Khujar.*

Monœcious, climbing to a considerable height. Stem stout 5-angled, twisted glabrous or slightly pubescent, often scabrous at the angles. Tendrils usually 2-fid. Leaves orbicular reniform in outline, 4-8 in. long, often broader than long, palmately 5 (rarely 7) lobed, the lobes acute or acuminate, lobulate and distantly denticulate, both surfaces finely scabrous, punctate, glabrous except the pubescent nerves beneath, base deeply cordate ; petiole 1-4 in. long, angular, slightly scabrous. Male flowers in axillary 4-20 flowered racemes, usually crowded near the top of the raceme ; peduncles 4-6 in. long ; pedicles $\frac{1}{4}$-$\frac{1}{2}$ in. long, pubescent, articulated near the apex, each bearing a small lanceolate glandular bract at, or more commonly, a little above its base ; buds ovoid, pointed. Calyx pubescent, $\frac{3}{8}$ in. long ; lobes lanceolate, acute, $\frac{1}{2}$ in. long. Petals spreading, 1 in. long, obovate oblong, yellow with green veins. Stamens 5, distinct. Female flowers solitary, usually from the

same axil as the males; peduncles short, 1-3 in. long. Staminodes usually 5, ovary cylindric or somewhat trigonous, blunt at the end marked with longitudinal lines. Seeds black or grey, $\frac{3}{8}$ by $\frac{1}{4}$ in., much compressed, narrowly winged, smooth or slightly tuberculate.

Flowers August to February.

Habitat

Throughout India very common, often cultivated. Distrib: cultivated throughout the tropics: native country uncertain (Naud.).

Medicinal and other uses

The seeds are said to be emetic and chathartic like those of *Luffa acutangula*. The fruit is edible and is used in curries, etc. The dry fruit, which is filled with an interwoven net work of fibre is used as a skin brush during bath.

Occurrence

Wall. Cat.	Botanic Garden, Calcutta, wild on the river side 17th Nov. 1915, Coll. D. M. Debbarman; Wall. Cat. 6715 B; Wall. Cat. 6755 A; Nathpur 27th Aug. 1810; Prome 1826; Irrawaddy 7th Sept. 1826; Sylhet. Wall. Cat. 6688 F;
Upper Gangetic Plain . .	Lucknow. 10th Nov. 1891, Co. Dr. Prain.
Sikkim	N. Bengal, Sikkim Terai, between Kuprail and Goredoora, in the jungles;
Bengal	Sibpur, Coll. S. Kurz; Badeca, E. Mymansing, 26th Nov. 1868; Rangamura, 500-850, Old Agartala, Hill Tipperah, Coll. P. M. Debbarman; Chittagong, November 1898, Coll. Mokim.
Assam	Tharia Ghant, Khasia, 28th Sept. 1867; Mont. Khasia 0-4,000 ft., Coll. J. D. H. & T. T.; Dhubri, June 1902, Coll. Sk. Mokim; Sibsagar Assam, May 1886, Coll. G. Manu.
Burma	Yammethin Dist., Kaing Reserve, 22nd January 1909, Nyanngbbin Reserve, Insein 18th Nov. 1935; Salween Dist., January 1912, Coll. A. Meebold; Keng Tung 4,000, S. Shan States, Coll. W. MacGregor; Pegu-yomah 25-1-68, Coll. S. Kurz; Shaimmagah 14th Jan. 1968; Coll. J. Enderson; Moulmein; Minbu September 1902, Sk. Mokim; Peguyomah 25th Jan. 1968, Coll. S. Kurz.
Sikkim	Pankabari 10/68, Coll. S. Kurz; Sikkim Terai, 10-11-57, Coll. T. & T.; Sivoke 28-10-78.
Peninsular India . . .	Sadivaiyal, Bolampatty valley 1,600, Coimbatore District, 25-2-1917, Coll. C. E. C. Fischer; Travancore, December 12-1894; Parambicolam, 3-4,000 ft., Cochin, Nov. 1910, Coll. A. Meebold.
C. India	June 1870.
Andamans	Cape Town, Coll. S. Kurz; S. Andaman, April 1890, Coll. G. King; Kamorta, Nicobar Isls., Coll. S. Kurz.
Malay Peninsula . . .	Kinta River banks, Perak December 1880, Coll. Dr. King's collector; Java.

3. ***Luffa acutangula*** Roxb. Hort. Beng. 70; DC. Prodr. iii, 302, Wall. Cat. 6759; Hook. f. in Oliv. Fl. Trop. Afr. ii, 530, excl. syn; Kurz. in Journ. As. Soc. 1877, pt. ii, 101, excl. many syn; *Cucumis acutangula* Wall. Cat. 6736.

Vern. Hind. *Torai, jinga, turi;* Beng. *Jhinga, jinga;* Uriya. *Jauhi;* Santal. *Paror jhinga;* Nepal. *Ramtoroi;* Mal. (S. P.) *Puichenggah;* Bundel. *Kali taroi, satpattiya;* N.W.F. *Terai, kali taroi, torai, salpatiya, jaginga;* Kumaon. *Torie;* Kangra. *Gherur gundoli;* Pb. *Kali tori, turai, jhinga;* Sind. *Turi;* C.P. *Dorka;* Bomb. *Turin ghisoda;* Dec. *Turai;* Tam. *Pikunkai;* Tel. *Burkai, birkaya;* Kan. *Hirekayi;* Tam. *Pikunkai;* Tel. *Burkai, bira kaya;* Malay. *Djinji;* Burm. *Tha-bwot-kha-wai; thapwot;* Sans. *Jhingaka;* Pers. *Khiyar.*

Monœcious, climbing to a considerable height; stems 5-angled, glabrous with sharp angles which are often scabrid. Tendrils usually 3-fid. Leaves orbicular in outline, pale green, 6-8 in. long and broad, palmately 5-7-angled or sublobate, scabrid on both sides, base cordate; nerves and veins prominent beneath; petioles 2-5 in. long, angular, scabrid. Male flowers in axillary 12-20-flowered racemes 4-6 in. long. Calyx pubescent obovate, yellow with green hairy veins. Stamens 3. Male flowers, solitary, in the same axils as the males; peduncles 2-4 in. long, ovary strongly ribbed. Fruit 6-12 in. long clavate-oblong tapering towards the base, very obtuse, smooth, longitudinally ribbed

(almost winged) with 10 sharp angles. Seeds ½ by ¼-⅓ in. ovoid-oblong, much compressed slightly corrugated on the sides, not winged, black. Very closely allied to *L. ægyptiaca* from which it differs in the number of stamens, the strongly ribbed ovary, the fruit and the seeds.

Flowers November to June.

Habitat

Cultivated extensively in North West India, Sikkim, Assam and Eastern Bengal; distributed to Ceylon and Malaya.

Medicinal and other uses

The seeds possess emetic and purgative properties but to a marked less degree than var. *amara*. Dr. Emerson states that the leaves are used locally in splenitis, hæmorrhoids and leprosy. Aitchison writes " the root is used in medicine ".

The juice of the fresh leaves is dropped in to the eyes of children in granular conjunctivities, also to prevent the lids adhering at night from excessive meibomian secretion. (Hon. Surgeon P. Kinsley, Chikakole, Ganjam. Madras).

Oil—The seeds of this species like those of the most other Cucurbitaceous plants yield an oil. It is believed to possess similar properties like the oil obtained from the melon.

The fruit is highly esteemed in India and is much eaten, either in curries or dressed with clarified butter, when half grown it is one of the best indigenous Indian vegetables, and when boiled and dressed with butter, pepper and salt is very palatable.

Occurrence

Wall. Cat.	Gongchora, 18th June 1809; 6736C; Royal Botanic Garden, Calcutta 6759 B;
Central India	Jodhpur, February March 1868; Marwar 1868, Coll. G. King; Guna, Coll. Dr. Barklay.
N. W. Prov.	Dehra Dun, 1870, Coll. G. King; N. W. India, Royle.
Beng.	Sibpur 5/67, Coll. S. Kurz; Bamunpukri 5 Nov. 76; Dacca 15th Sept. 1868, Coll. C. B. Clarke; Agartala 600-800 Hill Tipperah, Coll. P. M. Debbarman
Burma	Pegu, Paddy ridges, Coll. S. Kurz.
Laccadives	Minikoy, Dec. 7th, Coll. H.M.I.M., Investigator.
Peninsular India . . .	Gudur 3 Feb. 1929, Nelore Dist., Coll. K. Churian Jacobs.

Var. Amara Roxb. Fl. Ind. iii, 715 (sp.); Wall. Cat. 6754 A; W. & A. Prodr. 343; Dulz. & Gibs. Bomb. Fl. 102; Naud. in Ann. Sc. Nat. ser. 4, xii, 123; *L. Plukenetiana* ser. in DC. Prodr. iii, 302; *Momordica tubiflora* Wall. Cat. 6749; *L. amara* Roxb. Woodr. in Journ. Bomb. Nat. (1898), v. 11 p. 640.

Vern. Sans. *Koshatakh*; Hind. *Karvituri, karuotarui*; Beng. *Ghosha-lata, tilo-jhinga, tito-toroi, tito dhundul*; Dec. *Kurui turai*; Bomb. *Kodu sirola, kadu dorka*; Mar. *Kadu dodaka*; Tam. *Pepirkkam*; Tel. *Adavi-bira, chedu bira, veri bira.*

Leaves smaller, at first whitish and softly villous, at length scabrid. Flowers smaller. Fruit obovoid, obtusely conical at both ends, 2-4 in. long by about 1-1½ in. thick 10-ribbed, bitter. Seeds smaller.

Habitat

Met with all over India especially on the Western side.

Medicinal use

Roxburgh* first pointed out the medicinal properties of this plant. He remarks,—' Every part of this plant is remarkably bitter the fruit is violently cathartic and emetic. The juice of the roasted young fruit is applied to the temples by natives to cure headache. The seeds either in fusion

* Roxburgh, W. (1820) *Flora Indica* Ed. C.B.C. 24, 699

or raw, are used by them to vomit and purge.' In Pharmacopœia of India the plant is described as bitter, tonic and diuretic but the vernacular names applied to this plant as *Kerula* or *bindal*, it appears to be misrepresented for *Momordica charantia*. Dymock* writes, 'The leaves are bitter the fruit less so; the former in Bombay are used as an external application to sores in cattle. In dog bite the pulp of the fruit is given with water; it causes vomiting and purging. The juice is applied in different kinds of bites, and the dried fruit is used as a snuff in jaundice. The root with equal parts of the root of *Hibiscus rosa-sinensis* (vern. jaba) and *Hemidesmus* (vern. anantamul) is given with milk, cumin and sugar in gonorrhœa. From the following interesting note by Moodeen Sheriff it would appear that the seeds, if carefully prepared and administered, are of considerable value as a specific for dysentery. Should this prove to be correct, the drug would be a cheap, easily obtained and most valuable substitute for Ipecacuanha.

'The mature and dry seeds of both *Luffa acutangula* and *L. amara* are emetics, but the action of former is very irregular and uncertain. In some cases, they act in twenty to thirty-five grain dosses pretty satisfactorily, but in others they either do not act at all or act violently and continue to produce vomiting for many hours. On the other hand the action of the seeds of *L. amara* is very sure, safe and efficient in the same or somewhat smaller doses. The Hindu practitioners are aware that the fruit of *L. amara* is emetic but they do not know what particular part of it possesses that property. They use the seed and all other parts together in fusion. One entire fruit, generally of middle size, is bruised and infused in some cold water at night, and the liquid is strained through and administered in the morning. The action of this draught is generally very irregular, uncertain and often accompanied by gripping and is therefore very unsatisfactory. I have used the different parts of the plant separately and found the emetic property to reside in the kernel or cotyledons of the seeds. The seeds are dark brown, oblong or oval, flat rough with minute elevated dots, margin turned, and only distinct at the base. The length of the seed varies from one-third to half an inch, and the breadth from three to five line; the kernel is albuminous greenish white, very bitter and oily. The kernel of the seed is the best and forms the only vegetable emetic in India which is equal to Ipecacuanha in the same quantity. In smaller doses it is expectorant and also demulent, owing to its containing albumen and oil. In addition to the above properties it has a great control over dysentery. I have used this drug and also Ipecacuanha, separately, in several cases, in same manner and doses, and found it to be at least quite equal to the latter. The dose of the kernel as an emetic is from twenty to thirty grains; as a nauseant, from five to ten grains. When the kernel is rubbed and mixed with water it forms a greenish-white emulsion, which is the only form in which I have yet used it.' (Hon. Surgeon Moodeen Sheriff, Khan Bahadur, Triplicane, Madras.)

Occurrence

Peninsular India	Madras
Assam	Goalpara
C. I.	Marwar Rajputana, Guna, Aug. 1867, Coll. G. King
N. W. Himalaya	Dehra Dun, Sept. 1860, Coll. G. King

4. ***Luffa echinata*** Roxb. Hort. Beng. 104; Roxb. Fl. Ind. iii, 716; Wall. Cat. 6756; W. & A. Prodr. 343; Dalz & Gibs. Bomb. Fl. 102; Kurz. in Journ. As. Soc. 1877, pl. ii, 101. *L. Bindaal.*

Vern. Sind. *Jangthori*; Bomb. *Kukar-wel*; Guj. *Seeds-Wa-upla-bij*; Mar. *Seeds-Deodagri*; Tel. *Pani bera.*

A climber but not extensively; stem slender, branched, furrowed, glabrous. Tendrils 2-fid. Leaves $1\frac{1}{2}$-$2\frac{1}{2}$ in. long, usually a little broader than long, reniform suborbicular in outline broadly cordate at the base, obscurely 5-angled or more or less deeply five lobed, lobes rounded or rarely subacute at the apex the margins minutely denticulate; petioles 1-2 in. long, striate, puberulous or sometimes lightly scabrid; flowers usually dioecious. *Male flowers*: peduncles 3-6 in. long, usually in pairs, one 1-flowered, the other with a raceme of 5-12 flowers at the apex; pedicles $\frac{3}{8}$-$\frac{3}{4}$ in. long, bracteata near the base calyx hairy, $\frac{1}{4}$ in. long; tube very short; lobes ovate-lanceolate, acute,

† Dymock, W. (1885) *Materia Medica of Western India* 2nd Ed, 342.

Petals white, spreading, obovate twice as long as the calyx, veined. Stamens 3, two with 2-celled anthers. *Female flowers:* peduncles 1-2 in. long. Fruit broadly ellipsoid, 1-1½ by ½-¾ in., not ribbed, clothed with ciliated bristles ⅙-¼ in. long; operculum conical, without bristles. Seeds numerous ⅛-⅕ by ⅓ in., not winged, slightly verrucose.

Flowers August to December.

Habitat

Gujarat, Dalzell; Sind, Stocks; Purneah, Kurz; Dacca, C.B. Clarke. Distributed to tropical Africa.

Occurrence

Upper Gangetic Plain	Bahraich (Oudh) 10-7-98, Coll. Harsukh; Banda, U. P., Nov. 1901, Mrs. A. S. Bell
Central India	Isagarh Dist. Gwalior 1867, Coll. G. King; Ajmere, 27 Aug. 1875; Guna, Saugar, Chindwara Dist., C. P.
N. W. Himalaya	Swat valley, 3,000 ft., N. W. F. P., 17-9-95, Chitral Relief Expedition, 1895, Coll. Brig. Genl. Gatacre; Simla 31. Oct. 1864, Coll. Brandis
W. India	Bombay, 1878
Assam	Bonihat, Khasi Hills, 16. June, 1911, Coll. R. K. Das
Wall. Cat.	6756A; Chandalgar 30 Sept. 1813, 6756 B
Bihar	Dalsing Sorai, Darbhanga, Aug. 1910, Coll. Dr. Prian's collector; between Dingraghat and Purnea 30-12-68, Coll. S. Kurz

Var. *longistylis* Edgw. in Journal As. Soc. 1852, p. 270 (sp.)

Male raceme shorter than the leaves, spines of the fruit fewer themselves glabrous.—Banda, Edgeworth. The leaves are not more dissected than in some Bengal typical *L. echinata*, nor are the styles longer. The whole male receme is much shorter than the accompanying 1-flowered male peduncles.

Medicinal use

According to O'Shaughnessy* the fruit is considered in North India to be a powerful remedy for dropsy. S. Arjun† remarks that the fruit possess purgative properties. Dymock** writes, "I have not met with any notice of the medicinal use of this plant in European works on the Materia Medica of India." (The writer seems to have not noticed the observation of O'Shaughnessy and Arjun). Roxburgh‡ describes, "In the Bombay Presidency it is found mostly in Gujarat where it has a reputation among the Hindus on account of the bitter properties of the fruit, and is an ingredient in their compound decoction. In the Konkan a few grains of the bitter fibrous contents of the fruit are given in infusion for snake bite, and in cholera after each stool. In fevers the infusion is applied to the whole body, and in jaundice it is applied to the head and also given internally; the infusion has also a reputation as a remedy for colic. The dried vine with the ripe fruit attached is brought to Bombay for sale along with other herbs from the province of Gujerat."

5. *Luffa umbellata* M. Roem.

Synops. Pepon., ii, 63; L. Kleinii W. & A. Prodr. 344; *Cucurbita umbellata* Heyne in Herb. Rottler; Wall. Cat. 6724; D.C. Prodr. iii 318.

Young fruit spinous, spines densely wooly. Agrees closely with *L. echinata* and may be a variety of it but the stamens differ; the filaments being three, of which two are bifid below the stamens.

Habitat

Travancore, Klein; Coromandal (?) Wight.

8. Benincasa

In Bibl. Batal. 9, p. 158 cum icone (1818); in D C. Prodr. 303; Spach. Veg. phan. 6, p. 203; Meisn. Gen. p. 127 (91); Endl. Gen. p. 938; Arn. in Hook. Journ. of Bot. 3, p. 277; Wight in Ann.

* O'Shaughnessy, W.B. (1841) *Bengal, Dispens*, 346.
† Arjun, S. 1879 *Cat. Bomb. Drugs*, 59.
**Dymock (188 5) *Materia Medica West India*, 343.
‡Roxburgh, W. (820) *Flora Indica*, 24, 699.

and Mag. of Nat. Hist. 8, p. 269; Roem. Syn. fasc. 2, p. 14; Naud. in Ann. Sc. nat., ser. 4, v. 12, p. 87; Benth. et Hook. Gen. 1, p. 824; Hook. f. in Oliv. Fl. trop. Afr. 2, p. 532.—Cucurbitæ sp. Auct.

Benincasa, Savi.

A large climber, softly hairy, tendrils 2-fid. Leaves cordate, reniform orbicular, more or less fine lobed; petiole without glands. Flowers large, yellow, monoecious, all solitary, without bracts. *Male*: calyx tube campanulate, lobes 5, leaf-like, serrate; petals 5, nearly separate, obovate; stamens 3, inserted near the mouth of the tube, anthers exerted, free, one 1-celled, two 2-celled, cells sigmoid. *Female*: calyx and corolla as in the male; ovary, oblong densely hairy; style thick, with 3 flexuose stigmas; ovules numberous, horizontal; placenta 3. Fruit large, fleshy oblong, pubescent, indehiscent. Seeds many, oblong compressed, margined.

Benincasa hispida **Cogn.** in DC. Mon. Phan 1881 iii, 513; Wall Cat. 6723; Sampson, Kew Bull. Ser. 12, 1936, p. 20. *Benincasa cerifera* Savi.l.c.; W. & A. Prodr. 344; Miq. Fl. Ind. Bot. i. pt. i, 665; Naud. in Ann. Sc. Nat. Ser. 4, xii, 87; Kurz. in Jour. As. Soc. 1877, pt. ii, 101; *Cucurbita pepo Lour*. Fl. Cochin. 593; Roxb. Fl. Ind. iii, 718; *C. farinosa* Blume Bijd.; *Gymnopetalum calyculatum* Miq. Fl. Ind. Bat. suppl. 332.

The white gouard Melon.Vern.: Sans. *Kushamanda, Kuspandaha;* Beng. *Chalkumra*; Pb. *Petha, chalkumra, gol kaddu;* Hind. *Gol Kadu, kudmiah, Kondhza, Kumrha, petha, phuthia;* Kumaon *Kumhra, churja*; Mar. *Kohala;* Cutch. *Kushmand, Kohula;* Guj. *Bhura kola, Kholu;* Bomb. *Kohala, Koholen, goldaku*; Sing. *Golkadu*; Tam. *Kaliyana-pushinik-kay*; Tel. *Burda gumudu, brididi gunuandi, pendli gummadi-kaya*; Mal. *Kumpalanna, Kumpalama Kam Binde-kumbala-kayi;* Burma Kyank-payon.

Annual, softly hairy, stem stout, angular, tendrils 2-fid, leaves 4-6 in. diam., kidney-shaped, round, base notched, more or less deeply 5-lobed, stalks 3-4 in. without glands; flowers large, yellow, solitary, without bracts. Monœcious, male flowers on stalks 3-4 in., calyx tube bell-shaped, lobes 5, leaf like, toothed, corolla 5-lobed, ovate almost to the base, stamens three, almost on the mouth of the tube, anthers free, protruding. Female flowers, calyx and corolla as in the male style thick, with 3 zigzag stamens (syngenesious); fruit 12-18 in. long, oblong, fleshy, with a waxy bloom, seeds many oblong, flattened.

Habitat

Cultivated throughout India. Distributed through cultivation in Malaya, China, Japan; tropical Africa; no record of occurrence in wild state anywhere; according to DeCandolle it is a native of Japan and Java.

Affinity. Morphologically *Benincasa* resembles *Cucurbita* hence these groups may be placed side by side. From the anatomical stand point however *Benincasa* differs much from *Cucurbita* as the number of vascular bundles in the former, in the mid rib of the leaf is four and all arranged in a straight line while in the latter the bundles are seven in number all arranged in an ellipse, the largest of them being placed at the base. This difference in the number of vascular bundles are antagonistically speaking of their phylogenetic relationships. But from the phytogenetic stand point of the reduction of vascular bundles due to evolution, if we consider the side bundles of the midribs of *Cucurbita* are united, we at once arrived at an arrangement found in *Benincasa*. *Benincasa* is nowhere found in wild state in the world which gives further evidence of its highly evolved stage. Moreover Blume, Loureino and Wallich placed *Benincasa* as a species of *Cucurbita*. Watts writes, "This plant is so like the pumpkin that the earlier botanists took it for *Cucurbita*. To distinguish it from *Cucurbita pepo* DC., the following characters may be useful.—Stem and leaves softly hairy. Male flowers large solitary; petals 5, nearly free; stamens 3, inserted near the mouth of the tube anthers free exerted. Fruit 1 to $1\frac{1}{2}$ ft., cylindric, ribs, hairy when young and bright green, ultimately becoming smooth and covered with bluish white waxy bloom; pulp flesh white." Flowers April to November.

Medicinal and other uses

The fruit possesses alterative and styptic properties and is popularly known as a valuable anti-mercurial. It is also said to be cooling. It is considered tonic nutritive and diuretic and a specific for hæmoptysis and other hæmorrhages from internal organs. For this purpose the fresh juice from the fruit is administered, while a slice of the fruit is at the same time applied at the temples. According to the Sanskrit authors, it is useful in insanity, epilepsy, and other nervous diseases ; the fresh juice is given either with sugar or an adjunct to other medicines for this disease.

" It would appear that the older Sanskrit writers were not acquainted with its peculiar action on the circulatory system by which it rapidly puts a check to hæmorrhage from the lungs. The Raja Nirghantu, the oldest work on therapeutics, gives a long account of its virtues, but does not allude to its uses in phthisis or hæmoptysis. Neither does *Susruta* mention it in his chapters on the treatment of hæmorrhage and phthisis, though the plant is alluded to by him elsewhere. The more recent compilations such as, *Chakradatta*, *Ayurveda Sangraha*, *Sarangadhara*, etc. gives numerous preparations of the article and detail of its uses." " In preparing this medicine " in the form of confection " old ripe gourds are selected. Those not at least a year old are not approved. They are longitudinally divided into two halves and the pulp scraped out in thin flakes by an iron comb or scratcher. The watery juice that oozes out abundantly during this process is preserved, the seeds being rejected. The pulp is boiled in the above mentioned juice, till soft. It is then tied up tightly in a cloth and the fluid portion allowed to strain through it. The softened and drained pulp is dried in the sun and the watery portion is preserved for future use. Fifty tolas of the prepared pulp are fried in sixteen tolas of clarified butter, and again boiled in the juice of the fruit, till reduced to the consistence of honey. To this are added fifty tolas of refined sugar, and the whole is heated over fire, till the mass assumes such a consistence as to adhere to the ladle." The pot is then removed from the fire and a number of flavouring demulunt added, such as peeper, ginger, cumin, cardamons, cinnamon etc., the mixture being stirred until cold. Dose from 1 to 2 tolas according to the age and strength of the patient is prescribed. The seeds possesses anthelmintic properties and are useful in cases of tænia. The expressed oil of the seeds, in doses of half an ounce, repeated once or twice at an interval of two hours, and followed by an aperient, is said to be equally efficacious.

" The fresh juice is often used as a vehicle to administer pearl shell for the cure of phthisis in the first stage " (Asst. Surgeon S. Arjun, Bombay). " It is considered a specific in pulmonary consumptions. A country preparation made of the ripe fruit called *Kushandakhanda* is considered very efficacious in phthisis pulmonalis and I have seen people benefitted by it " (Surgeon K.D. Ghosh, Bankura). " This is so universally believed to be useful in pulmonary consumption that some trails should be made in order to discover whether it has any effect on the bacillus of phthisis. I have seen it produce a decided effect in arresting pulmonary tuberculosis " (Dr. Ghose, Khulna). " Preserve is given in piles and in dyspepsia as an antibilious food " (Surgeon Major W. Moir, Meerut). " This forms one of the chief ingredients of the vapour bath used in Syphilitic eruptions " (Asst. Surgeon A. C. Mukherjee, Noakhali). " The expressed juice of the mature fruit possess purgative and alterative properties. It is used in cases where the system has been effected by mercury " (Brigade Surgeon F. H. Thornton, Monghyr). " The preserve of the white lemon is an easily digestible and highly nutritious food in wasting diseases, as consumption " (Surgeon Major R. C. Dutta, Pubna). " Much used in diabetes with successful results, the juice of the cortical portion (4 oz.), combined with 100 grains of each of powdered saffron and bran of red rice, given morning and evening, with strict diet " (Surgeon E. W. Savinge, Rajamundry, Godavari Dist.). The most common way in which the juice is used is in the shape of a confection with sugar, etc., as a cooling and fattening medicine " (Native Surgeon R. Moodelliar, Chingleput, Madras Presidency).. " Useful in piles given with *surun*. Antidote to mercurial poisoning administered in the form of *pak* " (Surgeon W. Barren, Bhuj, Cutch).

The fruit of this plant excretes upon its surface a waxy substance which resembles the bloom found on plums and cucumbers. This is said to be produced in sufficient quantity to be collected and made into candles. The seeds also yield a mild, pale coloured oil.

It is often used in Indian cookery as a vegetable and as a curry. This fruit is also very often used in making sweetmeat, which consists of pieces of this gourd coated with sugar; this is said to have cooling properties.

Occurrence

Sikkim	Labdah 2,500 ft., 30-7-13; Labdah, Coll. C. G. Cave; Sukna 1,000 ft., 10-9-13 Coll. G. H. Cave
Assam	Danika river, Mahkotea, 4th April, 1895, Collected by the Reporter of the Economic Products to the Government of India; Alipur, 24 February, 1809
Andamans	Aberdeen 15-11-1889, Coll. David Prain
Bengal	Agartala 800—1,000 ft., Hill Tipperah, 29-9-14, Coll. P. M. Debbarman; R. B.G., Calcutta
Bihar	Cult., S. Kurz
Burma	Upper Burma, Shan 25. July 1893, Coll. Dr. King's collector
Punjab	1878, Dr. E. Sanders
Upper Gangetic Plain . .	Cultivated 14th May, 1901, Mrs. A. S. Bell

9. Momordica

Momordica Tourn. Instit. p. 103, tab. 29, 30; Linn. Gen. ed. 1, p. 296, edit. 6, p. 506; Juss. Gen, p. 395; Willd Spec. 4, p. 601; Ser. in D.C. Prodr. 3, p. 311; Spach, Veg. phan. 6, p. 219; Meisn. Gen. p. 127 (91); Endl. Gen. n. 5133; Roem. Syn. fasc. 2, p. 13; Miq. Fl. Ind. Bat., 1, part. 1, p. 663; Naud. in Ann. sc. nat., ser. 4, v. 12, p. 129; Sond. in Harv. et Sond. Fl. Cap., 2, p. 491; Benth. Fl. Austral., 3, p. 318; Benth. et Hook. Gen. 1, p. 825; Hook. f. in Oliv. Fl. trop. Afr., 2, p. 534; Boiss., Fl. Orient., 2, p. 757; Cogn. in Mart. Fl. Bras. fasc. 78, p. 13; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 616.

Climbing annual or perennial herbs. Leaves entire, lobed or pedately 3-7 foliate. Tendrils simple or bifid. Flowers yellow or white, monœcious or diœcious. Male flowers corymbose or racemose. Calyx-tube short, campanulate, closed at the bottom with 2-3 incurved oblong scales; lobes 5, corolla usually 5-partite to the base or nearly so, rotate, or broadly campanulate, segments ovate, cordate, stamens 3 (2 in *M. cymbalaria*), inserted on the mouth of the calyx tube; filaments *short*, free; anthers at first cohering, at length free, one 1-celled, the others 2-celled, the cells flexuose (rarely short and straight or curved), connective not produced at the apex. Rudimentary ovule 0 or glanduliform. Female flowers solitary. Calyx and corolla as in the male. Rudimentary stamens 0, or 3 glands surrounding the base of the style. Ovary oblong or fusiform, 3-placentiferous; ovules many, horizontal; styles slender; stigmas 3. Fruit oblong, fusiform or cylindric, baccate, indehiscent or 3-valvate, few or many seeded. Seeds tumid or flattened, smooth or variously sculptured. Species 25.

Distrib. Cheifly African a few scattered through the both hemispheres.

The occurrence of cystoliths of calcium carbonate in the epidermal cells of the under surface of the leaf is a remarkable characteristic of the genus *Momordica*. These cystoliths are aggregated from single to as many as eight groups. Calcium oxalate in the form of crystals are also abundantly met with in the stem and root of this genus.

Key to the species

A. Male peduncles 1-flowered
- B. Flowers monœcious
  - C. Bracts of male flowers about the middle or below the middle of the peduncle; cystoliths regular . . . . 1. *M. charantia*
  - CC. Bracts of the male flowers at the apex of the peduncle . . . . 2. *M. Balsamina*
- BB. Flower diœcious
  - C. Petioles without glands
    - D. Leaves smaller, peduncles longer than the petiole, sepals linear, lanceolate . . . . 3. *M. dioica*
    - DD. Leaves large, peduncles shorter than the petiole, sepals oblong . 4. *M. macrophylla*
  - CC. Petioles glandular, cystoliths irregular . . . . . 5. *M. cochinchinensis*

AA. Male peduncle several flowered
- C. Flowers monœcious, leaves ovate lanceolate . . . . . . 6. *M. denudata*
- CC. Flowers diœcious leaves reniform orbicular . . . . . 7. *M. Cymbalaria*

1. **Momordica Charantia** Linn. Sp. Pl. 1009; Roxb. Fl. Ind. iii, 707; W. & A. Prodr. 348; Bot. Mag. t. 2455; Miq. Fl. Ind. Bat. i. pt. i. 663; Wight Ic.t. 504; Dalz. & Gibs. Bomb Fl. 102; Naud. in Ann. Sc. Nat. Ser. 9, xii, 131; Kurz. in Journ. As. Soc. 1877, pt. ii, 102; *M. humilis* Wall. Cat. 6747; *M. muricata* DC. 1. c.; *M. senegalensis* Lamk., Encyc IV, 239; *Cucumis africanas* Bot. Reg. t. 980.

Vern. Sans. *Sushavi, karavallilata, karavella;* Hind. *Karela, karali, karola*; Beng. *Karala, uchchhe*; Uriya *Karena*; Assam. *Kakrel, kakiral;* N. W. P. *Karela, karola;* Kumaon. *Kurela*; Pb. *Karela, karila*; Sind *Karelo*; C.P. *Karli*; Bomb. *Karla;* Mar. *Karli, karala*; Guj. *Karela, kareto, karelu*; Dec. *Karela*; Tam. *Pavkka-chedi, pava kai*; Tel. *Kakara, ura kakara, tella kakara, metta kakara*; Kan. *Kagala-kayi*; Malay *Kaipa valli*; *pavakka chati, panti-pavel, kappakka;* Burm. *Ka-hin-ga-bin, kyet-hen-kha*; Sing. *Karawita, battu-karawilla.*

Annual; stem 3-6 ft. long, much branched, angled and grooved, more or less pubescent or hairy; young parts hairy or villous. Tendrils simple, slender, elongate, pubescent. Leaves almost orbicular in outline 2-5 in. on diam., pubescent or subglabrous on both sides, cordate at the base, deeply divided into 5-7-lobes, the lobes acute or subacute, apiculate, coarsely spinous—dentate, constricted at the base, the sinus between them narrow, rounded; petiole 1-2 in. long, channelled, pubescent. Flowers monœcious. *Male flowers :* solitary; peduncles 2-4 in. long, bract at or below the middle. Calyx $\frac{1}{3}$-$\frac{3}{8}$ in. long, pubescent; lobes $\frac{1}{5}$-$\frac{1}{4}$ in. long, elliptic, subacute. Corolla somewhat irregular, lemon yellow, segments obtuse or emerginate, $\frac{2}{3}$-$\frac{3}{4}$ in. long, veined. *Female flowers*: peduncles 2-4 in. long, slender, bracteate usually at or near the base. Staminodes 3, glanduliform. Ovary fusiform, muricate, stigmas 3, bifid. Fruit bright orange coloured, when ripe green when young, 2-6 in. long, pendulous, fusiform, usually pointed or beaked, ribbed, and bearing numerous triangular tubercles giving it the appearance of a crocodile's back (Grahm), 3-valved at the apex when mature. Seeds $\frac{1}{3}$-$\frac{1}{2}$ in. long, compressed, corrugate on the margin, sculptured on both faces.

Flowers September to January.

There are two extensively cultivated varieties in India, differing in the form of the fruit, the one being longer and more oblong and the other smaller more acute, muricated and tubercled placed under var. *muricata* W. & A. These varieties go by the name of *Karala* and *uchhya* in Bengal.

Var. muricata W. & A. Beng. *Uchheye*	Var. proper Beng. *Karala*
(1) Leaves faintly nerved	(1) Leaves prominently nerved.
(2) Peduncles with a round or reniform bract near the base	(2) Peduncle with a round or reniform bract at or below the middle of the base
(3) Fruit small, acute at ends lengthened, tuberculed, tapering at both ends	(3) Fruit large, oblong, gibbous, muricated, with tubercles between, tapering at both ends.

Habitat

Throughout India, cultivated. Distrib. Malaya, China, tropical Africa.

On the lower surface of the leaf of *Momordica charantia* innumerable groups of cystoliths of the calcium carbonate are found. These cystoliths are encased in the enlarged lower epidermal cells. They are generally arranged in double groups or some times in groups as many as seven.[1]

Medicinal and other uses

The fruit is considered tonic, stomachic and cooling and is used in rheumatism, gout and diseases of the spleen and liver. Rumphius[2] states that it was much esteemed in Amboina, where it was supposed to purify the blood, and to dissipate melancholy and gross humours. The fruit and leaves are both administered internally in leprosy, piles, jaundice, and as an anthelmintic. The latter are said by Rumphius to be used by Indian obstetricians to purify the blood and generate milk in the puerperal condition. He states also that a leaf was placed in the mouth of the newly born infant to clear its breast and intestine of all mucus, excrement, etc. Dymock[3] reports that in Konkan a third of a seer of the leaf juice is given in bilious affections as an emetic and purgatives, alone or combined

[1] Chakravarty (1937). *Philipp J. Sc.* 63,409
[2] Rumphius (1741) *Herbarium Amboinense* 5, t. 151
[3] Dymock. W. (1885). *Materia Medica, West India* 340

with arometics ; it is also applied externally for burning of the soles on the feet, and round the orbit as a cure for night blindness. The fruit of the cultivated form is said to act as a febrifuge. The root is also used medicinally being considered astringent and warm ; and in the Punjab is, according to Honigberger (ex D.E.P.) applied externally to piles. The whole plant combined with cinnamon, long pepper, rice, and the oil of *Hydnocarpus Wightiana* Bl., is employed by the Hindus as an external application in scabris and other cutaneous diseases.

" A case of death from violent vomitting and purging caused by the administration of this juice to a child has fallen in my practice " (Asst. Surgeon, S. Arjun, Bombay). " The fruit is used as a vegetable, cooked as curry. It is bitter and possesses wild laxative, antibilious and tonic properties " (Civil Surgeon D. Basu, Faridpur, Bengal). " The expressed juice with chalk is used in apthæ, and is also as an emmenogogue in dysmenorrhœa. It is applied externally to the scalp in pastular eruptions " (Surgeon Major D. R. Thomson., Madras). " Useful as an application to burns, and allays the irritation of boils. Commonly prescribed as an anthelmintic, and as a purgative for children " (Civil Surgeon, J. Mc-Conaghey Shajahanpore). " The fruit is anthelmintic " (U.Ummegudien).

The young fruit is highly esteemed as a vegetable in Indian cookery. The fruit of the variety *muricata* though much smaller is more esteemed. This is found in abundance in every market. Treatment in hot water and salt is necessary previous to cooking or frying to take away a portion of the bitterness.

Occurrence

Peninsular India . . .	Rampha chodavaram, Travancore State, Sept. 1920, Coll. V. Narayanaswami; Kalla, 1-9-1913, Coll. C. C. Calder and M. S. Ramaswami ; Quilon, Travancore, 11-11-13, Coll. R. Rama Rao ; Karianshola, Anamalai Hills 2,400 ft., 1-10-1912 Coll. G. Thomson ; Kolathur, Coimbatore, 17-1-06, Coll. C. E. C. Fischer, Madras ; Cuddupah 500 ft., July 1885, Coll. G. S. Gamble ; Bombay, Adyar Jan. 1876
Wall. Cat.	Royal Botanic Garden, Calcutta ; Patna 16. April 1812, 6765 B ; Catiram 3 March 1808, 6745 B ; Kaliganj, 26 February 1809
Bengal	Old Agartala 500-800 ft., Hill Tipperah, 31-12-14, Coll. P. M. Debbarman ; Chittagong, November 1890, Coll. Mokim ; R.B. G., Calcutta ;
Rajputana	Marwar, 1868, Coll. G. King
N. W. Himalaya . . .	Baddi outer Himalaya, Coll. Dr. Brandis ; N. W. India ; near Mussoorie, 3. Oct. 1870, Coll. Dr. King
Upper Gangetic Plain . .	Lucknow, May 1854
Bihar	Chota Nagpur, 9 January, 1878, Coll. J. J. Wood
Assam	Kamrup plains, Sibsagar ; November, Coll. Dr. King's collector, Gawhati, August, 1860 ; Mangalai March 1902, Coll. A. C. Chatterjee
Sikkim	Teesta 12-8-14, Coll. C. H. Cave ; below Sureil Aug. 20, 19th Coll. G. H. Carter ; Little Ranjiet valley 2,500 Coll. S. Kurz ; October 1868, Coll. S. Kurz
Burma	Cultivated on the Island opposite Minbu town 8th March, 1703, Coll. Aubert and Gage ; Pegu Yomah, Coll. S. Kurz
Laccadives Isls . . .	Minikoy, Coll. H. M. I. M. Investigator 1891, 6th December.

2. ***Momordica Balsamina*** Linn. sp. Pl. 1009 ; Miq. Fl. Ind. Bat. i. pt. i, 664 ; Boiss, Fl. Orient, ii, 757, excl, syn. Wight ; Hook. f. in Oliv. Fl. Trop. Afr. ii, 537, not of Wallich, nor of W. & A. Prodr. 349 ; Woodr. in Journ. Bomb. Nat. ii (1898) p. 640 ; Aitch, Pb. & Sind. Pl. p. 63 ; Hook. Fl. B.I. **2**, p. 617 ; Watt. Dict. Econ. Prod., **5**, p. 256.

Vern. Sind *Kurelo-jangro* ; C. P. *Mokha* ; Arab. *Mokah*.

Monoecious ; stem 2-5 ft. long, very slender, branched, grooved subglabrous, orbicular in outline, $1\frac{1}{2}$-3 in. in diam., cordate at the base with a broad sinus, palmately 3-5-lobed to about the middle, the lobes rhomboid deeply lobulate, acute and mucronate at the apex, usually constricted at the base, the sinus between the lobes broad and rounded ; petioles $\frac{1}{2}$-$1\frac{1}{4}$ in. long, striate, pubescent. *Male flowers* : peduncles 1-flowered, slightly pubescent at the apex, otherwise glabrous or nearly so, slender, 1-3 in. long ; bract towards the apex of the peduncle, $\frac{1}{4}$-$\frac{3}{8}$ in. wide, cordate, orbicular denticulate, variegated green and white, reticulately veined. Calyx $\frac{3}{8}$ in. long, pubescent ; lobes in. long 5-7-nerved, triangular, acute, with a long slender mucro. Corolla subregular, yellowish with a dark base $\frac{1}{2}$ in. long obovate, subobtuse, reticulately veined, sometimes apiculate. Anther cells

flexuous, the connective broad. *Female flowers*: peduncles $\frac{1}{5}$-$\frac{1}{2}$ in. long, usually ebracteate or bracteate at the base. Calyx tube linear lanceolate, ovary fusiform, beaked, verucose. Fruit 1-3 in. long, ovoid narrowed to both ends, rostrate, smooth or muricate. Seeds ash coloured, ellipsoid, compressed, $\frac{3}{8}$ by $\frac{1}{4}$ by $\frac{1}{10}$ in., regulose on the flat faces and with a grooved margin which is tuberculate on the edges.

Flowers February to March.

Habitat

Punjab T. Thomson, Edgeworth; North-west India; Royle; Sind; Stocks. Distributed to Malaya, Australia, Western Asia, Africa to the Cape.

Medicinal use

According to Atkinson*, it is occasionally employed in native medicine. Ainslie† writes "The fruit, Hasselquist informs us in his *Iter Palestinum*, is famous in Syria for curing wounds; it is a fleshy ovate berry, ending in acute points. The natives cut it open and infuse it in sweet oil, which they expose to the sun for some days, until it becomes red, and then preserve it for use; dropped on cotton, and applied to fresh wounds they consider it as a vulnerary, little inferior to the balsam of Mecca."

Food—The young fruit is eaten as a pickle; when ripe it is 1 to 3 inches long, rostrate and orange-red, and is eaten as a vegetable in stews, etc.

Occurrence

Rajputana	Marwar, March 1868, Coll. G. King
W. India	Sind

3. ***Momordica dioica*** Roxb. ex Willd. Sp. Pl. iv. 605; DC. Prodr. iii, 312; W. &. A. Prodr. 348; Wight Ic. tt. 505, 506; Jacq. Voy. Bot. t. 71; Dalz. & Gibs. Bomb. Fl. 102; Naud. in Ann. Sc. Nat. Ser, 4, 4, xii, 133; Thwaites Enum. 126, as to a var. a.; Kurz. in Journ. As. Soc. 1877, pt. ii, 102; *M. Balsamina* Wall. Cat. 674, IA, B; W. & A. Prodr. 349, not of others; *M. Wallichii* Roem. Synop. 58; Miq. Fl. Ind. Bat. i. pt. i, 664; *M. renigera, Hamiltoniana* and *Heyneana* Wall. Cat. 6743, 6744, 6748; *M. Missionis* Wall. Cat. 6739; Dennst in Miq. l.c. *M. subacutangula*, Blume ex Kurz. Journ. As. Soc. 1877, pt. ii, 102; *Trichosanthes Russeliana* Wall. Cat. 6696 L; Hook. Fl. B. I. **2**, p. 617; Watt. Dict. Econ. Prod., 5, p. 258.

Vern. Sans. *Vahisi*; Santal *Kanchan arak* (leaf). *karla* (fruit); Assam *Bat karila*; N. W. P. *Gol kandra, gol-kankra, ghosalphal*; Pb. *Dhar karela, kirara*; C. P. *Kalwal*; Bomb. *Kurtoli, kartola, karantoli, vantha-karatola*; Mar. *Kartoli*; Guz. *Kuntola, kantolan*; Dec. *Kurtoli*; Tam. *Palupaghal-kalang*; Tel. *Puagakara, agakara*; Kan. *Gidnagula*; Malay. *Erimapasel*; Burm. *Sapyit, sabyet.*

Dioecious, perennial, with tuberous roots; stem, slender, branched furrowed, glabrous and shining. Tendrils simple, elongate, striate, glabrous. Leaves membranous, broadly ovate in outline, variable, $1\frac{1}{2}$-4 by $1\frac{1}{4}$-$3\frac{3}{4}$ in., cordate at the base glabrous, minutely punctate entire more or less deeply 3-5-lobed, the lobes triangular, ovate or oblong, distantly denticulate; petioles $\frac{1}{2}$-$1\frac{3}{4}$ in. long, channelled above, pubescent, eglandular. *Male flowers*: peduncle solitary, 1-flowered $1\frac{1}{2}$-5 in. long, slender, angled, usually pubescent near the top, otherwise glabrous; bracts cucullate, inserted a little between the flower and inclosing it, orbicular-reniform, $\frac{1}{2}$-$\frac{3}{4}$ in. broad, usually pubescent on both sides, strongly nerved, often ciliolate. Calyx-lobes distant $\frac{1}{5}$-$\frac{1}{3}$ in. long linear lanceolate. *Female flowers*: peduncles nearly as long as those of the male, usually with a small bract near the base. Ovary clothed with long soft papillæ. Fruit 1-$2\frac{1}{2}$ in. long, ellipsoid, shortly beaked, densely echinate with soft spines. Seeds many, $\frac{3}{8}$ in., broadly ellipsoid, slightly compressed, slightly and irregularly corrugated, enclosed in red pulp.

Flowers June to August.

* Atkinson, E. T. (1881). *Econ. Products N-W Provinces*, 7

† Ainslie, W. (1826). *Materia Medica 2*, 275

Habitat

Throughout India, from the Himalaya to Ceylon and Singapore, ascending to 5,000 ft. on the hills. Distrib. Malaya.

Medicinal use

The mucilaginous tuber is used medicinally, especially that of the female plant, which is larger than that of the male. Ainslie states that the Hindu doctors prescribe the mucilagenous root in the form of electuary in cases of bleeding piles, and in certain bowl-affections connected with such complaints, the dose about two drachms or more are prescribed twice daily. Rheede states (ex D.E.P.) the plant is "truly cephalic", for mixed with cocoanut pepper, red sandal wood and other ingredients to form a liniment it relieves all pain in the head. Dymock§ stated that the juice of the root is a domestic remedy in Konkan for the inflamation caused by contact with the urine of the house-lizard.

"The powder of the dried fruit introduced into the nostrils is said to give rise to repeated sneezing" (Surgeon Major W. D. Stewart, Cuttack). "The tuberous root of the female plant is used in Belgaum as an expectrant, and externally in ague cases as an absorbent. The root of the male creeper is used in ulcers, especially those caused by snake bites". The unripe fruit is used as a vegetable and given as a delicacy to patients recovering from fever" (C. T. Peters, Zundra).

Food—The green fruit is eaten in curries. The tuberous root of the female plant are also eaten.

Occurrence

Burma	Bhamo, 14-2-68, Coll. J. Anderson; Southern Shan States, Laihka, 1894, Coll. Abdul Khalil; Keng Tung 5,000 ft., June 1909, Coll. Capt. R. M. MacGregor
Bengal	N. Bengal, Sikkim Terai, below Goreedora, 30-9-68, Coll. S. Kurz; Chandernagar, August 1902 Coll., Abu Hosen; Lauhajong, Vikrampore, Dacca, 11 Aug. 1871, Coll. C. B. Clarke; Jatta Pagoda, Sundriban, 7 Aug. 1902, Coll. D. Prain; Agartala 500-800 ft., Hill Tipperah 9-6-15, Coll. P. M. Debbarman
Assam	Haflong, N. Cachar, 2,675 ft., 10-8-1908, Coll. W. G. Craib; near Badarpur, Dist. Sylhet, 12 Aug. 1903, Coll. A. T. Gage; Umran to Umling along Shillong Gauhati Road, 16 June 1911, Coll. R. K. Das; Khasia; Mount Khasia, Coll. J. D. Hooker & T. Thomson; Kohima, Naga hills Dist. July 1886, Coll. D. Prain; Deongaon, July 1843; Dimapur, 400 ft. Sibsagar Dist., Coll. C. B. Clarke
Bihar	Dalsing Sarai, Darbhanga Dist., Aug. 1900; Coll. Dr. Prain's collector, Manbhum Coll. Rev. A. Campbell
C. I.	Abu 1868, Rajputana Coll. S. Kurz; Guna, Isagarh Dist, Gwalior, Sept. 1867, Coll. G. King; Chanda, C. P., Coll. Reporter of Economic Product, Govt. of India; Chanda, C. P., 6th February, 1904, Coll. Reporter of Economic Products, Government of India
Punjab	1,000 ft., Coll. T. Thomson
N. W. Himalaya	Dehra Dun U. P., 20 July 1870, Coll. G. King; near Dehra August 1882, Coll. Duthie; Dehra Dun, July 25th 1870, Coll. G. King; Anadra Aug. 1868, Coll. G. King; N. W. India
Sikkim	Coll. G. King; above Goreedora towards Punkabari, 30-9-68, Coll. S. Kurz; Sikkim, 24-8-57, Coll. T. Thomson; Sikkim, 3-6,000 ft., Coll. J. D. Hooker; Pankabari July 1975, Coll. W. Gamble; Ryang 2,000 ft., 19th August 1874, Coll. G. King; Sikkim, Coll. S. Kurz;
Pen. India	Travancore, Coll. Rama Rao; Mundomurhi, Travancore State 27.8.1913, Madras Coll. C. C. Calder and M. S. Ramaswami; Courtalum, Tinnevelly Dt., Madras 17 June, 1901; Karianshala, Anaimalai Hills 2,450 ft.; Madras-Cochin 1-10-12, Coll. C. E. C. Fischer; Shevaroy Hills; Mysore and Carnatic Coll. G. Thomson; Bodinaikanur, December 1910, Coll. A. Meebold; Quilon, Salem Dist, Travancore, Madras, June 1836; Mandandurai 700 ft., Tinnevelly Dist., 19 February 1913, Coll. D. Hooper & M. S. Ramaswami; Balugaon, Chilka lake, Ganjam Dist., 8 August 1913, Coll. D. Hooper; Karwar, N. Kanara, Dist. Bombay, 20 Aug. 1883, Coll. W. A. Talbot;
Wall. Cat.	Prome, Burma 18th Sept. 1826; 6743 A; Chittagong, Bengal 6743 A; Sylhet Assam 6743 B;

§ Dymock, W. (1885). *Materia Medica West India*, 339

4. ***Momordica macrophylla*** Gage. Rec. Bot. Survey of India, iii, no. 1, p. 61.

Branches angled and grooved, sparsely scurfily hairy in the grooves. Leaves petiolate, cordate, mucronate, with base cuneate at the insertion of the petiole, membranous glabrous or with a few scurfy hairs on the nerves, margin entire, basal nerves 3 including the midrib, the lateral ones almost at once dividing into two branches. Petiole 6 cm. long with one or more glands, lamina of fully developed leaf 13-8-16 cm. long ; 11-14 cm. broad at its widest part. Tendrils unbranched. *Male flowers* usually solitary or unbranched peduncles, sometimes three or four on as many pedicles, branching from a main peduncle. Peduncles shorter than the petioles. Bract broadly reniform entire, about 3 cm. from base to apex, about 3·8 cm. in transverse diameter, at the top of the peduncle completely enclosing the male flower. Flower unexpanded about 22 cm. long. Sepals oblong acute, thick and rather fleshy in the bud, twisted, pubescent. Petals yellowish without a black base. Stamens three, two 2-anthered, one 1-anthered, filaments black. *Female flowers :* on solitary and unbranched peduncles, very small braceteole at the middle of the peduncle, no bract encloses the female flower. Flower about 2 cm. in length. Sepals oblong acute, 8 mm. in length. Petals yellowish ovary oblong acute, spinscent. Ripe fruit about 6·5 cm., spinescent, spines 5-7 cm. long.

Flowers March to August.

Habitat

This species is confined to Burma. It was first collected by G. Gallately in 1877 and afterwards in 1903 by Col. A. T. Gage and subsequently by J. H. Lace (1908) and N. Anandale (1917). I have found in growing wild in the suburban areas round about the district town of Henzada (Burma). It climbes to a considerable height on the trees and the fruits hang down.

Occurrence

Burma . . . . . . near Thoudaung, Maymyo Mandalay Road, Mandalay Dist., 24th August 1912, Coll. J. H. Lace ; Keng Tung 3,000 ft., S. Shan States, June 1909, Coll. R. W. MacGregor ; Tenasserim, Taepo 5,000 ft., 15-4-1877, Coll. Geo. Gallately ; Pomin River side—Minbu, Sept. 1902, Coll. Shaik Mokim ; Yawnghime, 5th March 1917, Coll. N. Anandale ; Maymyo plateau 3,500 ft., 12th July 1908, Coll. J. H. Lace

5. ***Momordica cochinchinensis*** Spreng. Syst. iii 14 ; Kurz. in Journ. As. Soc. 1877. pt. ii, 102, *M. mixta,* Roxb. Fl. Ind. iii, 709 ; W. & A. Prodr. 349 ; Miq. Fl. Ind. Bat. i, pt. i, 664 ; Bot. Mag. t. 5145 ; Naud. in Ann. Sc. Nat. Ser. 4, xii, 132 ; *M. diocia* Wall. Cat. 6750 A.B.C.D.E.F.; *Muricia cochinchinensis* Lour. Fl. cochinch. 733 ; DC. Prodr. iii, 318 ; Woodr. in Journ. Bomb. Nat. (1898) ii p. 640 ; Watt. Dict. Econ. Prodt. v. 5, p. 257 ; *Momordica mixta* Roxb.

Vern. : Sans. *Karkatka* ; Hind. and Beng. *Kakrol, kankur* (East. Bengal) Tel. *Adadi kakara ;* Burma *Samong uway.*

A strong climber often ascends on trees, dioecious ; root tuberous, perennial ; stem robust, angular, glabrous ; tendrils simple stout, angled, glabrous ; leaves suborbicular in outline, cordate at the base. 4-7 in., long and broad, glabrous on both surfaces, the margin near the base furnished with umbilicate glands, divided to the middle or almost to the base into 3 (rarely 5) lobes, the lobes ovate or oblong, lanceolate, acute or acuminate, diverging, the margins entire or faintly toothed ; petioles 2-3 in. long, stout, sulcate, almost invariably glandular at the middle and at the apex, glabrous or nearly so. *Male flowers* : peduncles 1-flowered, 2-6 in. long, angularly furrowed, more or less pubescent especially near the apex, bract at the top of the peduncle embracing the flower, broader than long, $1\frac{1}{3}$-$1\frac{2}{3}$ by $1\frac{1}{2}$-2 in., cordate at the base, pubescent or scabrid. Calyx hirsute or scabrid ; lobes $\frac{1}{2}$-$\frac{2}{3}$ in. long, oblong lanceolate, acute. Corolla white tinged with yellow ; pubescent outside more or less so inside ; segments reaching $2\frac{1}{2}$ by 1 in., obovate oblong or elliptic oblong, obtuse or subacute. *Female flowers* : peduncles 1-2 in. long with a small bract about the middle. Fruit 4-6 in. long, ovoid pointed, red, fleshy, terete, densely, covered with raised points about $\frac{1}{8}$ in. long. Seeds numerous, $\frac{7}{8}$ by $\frac{5}{8}$ by $\frac{1}{5}$ in. ovoid, much compressed, sculptured on both faces.

Flowers March to August.

Habitat

Bengal to Tenasserim common; Deccan Peninsula Wight; Kanara; Law; distrib. Formosa, Philippines.

Medicinal and other uses

It is stomachic and stimulant and is used in cough.

The fruit is occasionally used for food in Bengal.

In the inner epidermal cells of the leaves innumerable cystoliths of calcium carbonate of various fantastic structures are found. These cyslotiths unlike those of *M. charantia* are branched and heteroplanous.*

In the stem, root and the petiole crystals of calcium oxalate of various systems are also met with in quantity.

Occurrence

N. W. P.	Saharanpur, 19-8-01
Bengal	Royal Botanic Garden, Calcutta; Howrah Dist., June, 1869, Coll. S. Kurz; Chittagong, I.L. Lister, 1876; Chittagong Hill Tracts, Dr. King's collector
Assam	near Badarpur 12th Aug. 1903, Coll. A. T. Gage; Tingale Bam jungle, March 1899, Coll. Dr. Prain's collector; W. Phasama, Naga Hills, 1886, Coll. Dr. D. Prain; Sibsagar July 1845, Coll. Jenkins; Sylhet, Coll. J. D. H. & T. T.; Karimganj, Sylhet, 12th May 1868.
Wall. Cat.	Royal Botanic Garden, Calcutta; 6750 C; 6750 D; Kogun, 11th March, 1827 6750 F; Sylhet, 6750 B.
Burma	Tanbingon Rest House, 150 ft., Bank of Myaung strem, Tharrawaddy Dt., Coll. C. Gilbert Rogers; Mergui, April 1911, Coll. A. Meebold; Letpanthaung March 1911, Coll. A. Meebold; Thaungyu valley, Tidokui Chaung, Thanton Dist., 7th March, 1909, Coll. I. H. Lace.
Andaman	1884, Dr. King's collector; Coattu Tang near Port Blair, 6-8-84, Dr. King's collector; Ranguchang Hill jungle 3-11-1893, Coll. Dr. King's collector; Dhani Khari hill jungle S. Andaman, 13-10-1894, Coll. Dr. King's collector; Hobdaypur hill jungle S. Andamans 9-4-92, Dr. King's collector.
Malay Peninsula	Salean River, Pahang; Kelan Tujor, Perak, April 1892, Coll. L. Wray Jr.; Hulu Kenas, May 1884, Coll. B. Scortechini; Ayer Laml. Perak, June 1888, Coll. L. Wray Jr.; Perak 500-6,000 ft., June 1884, Coll. Dr. King's collector; Pachang, Ridley 1448 (et n. 2449); Penang; Siam; Pahang Track, State of Selangor, 1897.

6. ***Momordica denudata*** Hook. f. Brit. India II. 618.

Diœcious. A slender climber, nearly glabrous, tendrials simple. Leaves ovate-lanceolate, 2-4 by 1-2 in. deeply cordate, often 2-5 angled or sparingly 3-5 lobed, central lobe always long acute; petiole 1 in. Flowers small many males on one raceme with inconspicuous bracts. Male peduncles 2 in. often somewhat panicled nearly from the base and 10-12 mostly pedicelled flower; bracts at the base of the pedicles minute; sepals ovate, acuminate; petals $\frac{1}{5}$-$\frac{1}{3}$ in. filaments 3 inserted near the base of the calyx tube, anthers much exert, canduplicated. Female peduncle 1-flowered, about as long as the male bract minute near the middle. Fruit ovoid rostrate muricated with triangular papillæ $\frac{3}{4}$ in. long and broad.

Habitat

Ceylon, alt. 3000-4000 ft., Gardner, Thwaites, Walker.

Occurrence

Peninsular India	Kavalay Cochin 2,000 ft., November 1710, Coll. A. Meebold; Trichoor, Travancore, Sept. 1884, Coll. G. S. Gamble,

* Chakravarty *Philipp. J. Sci.* (1937), 63, (4), 415

7. ***Momordica Cymbalaria*** Fenzl, ex Naud. in Arn. Sc. (1859) Nat. Ser. iv. xii 134 ; Hook F. In Oliv. Fl. Trop. Afr. ii. 540 ; *Luffa tuberosa* Roxb. Hort. Beng. 104 ; Fl. Ind. iii, 717 ; W. & A. Prodr. 344 ; *L. amara* Wall. Cat. 6754 B. Woodr. in Journ. Bomb. Nat. (1898) v. ii p. 640 ; *Momordica tuberosa* Cogniaux. in DC. Monogr. Phan. (1881) v. 3 p. 454.
Vern. : Mar. *Kadavanchi.*

Monoecious ; root woody, tuberous, perennial ; stem very slender, scandent, branched, striate, pubescent or subglabrous. Tendrils filiform, slightly pubescent, simple. Leaves orbicular reniform in outline, $\frac{3}{4}$-$1\frac{1}{2}$ by 1-2 in., glabrous with a few scattered hairs, punctate (but not scabrid) on both surfaces, deeply cordate at the base, obtusely but not deeply 5-7 lobed, lobes short, acute or obtuse ; petioles $\frac{1}{2}$-$1\frac{1}{2}$ in. long, striate, pubescent. *Male flowers* ; in 2-5 flowered racemes ; peduncles $\frac{1}{4}$-1 in. long, filiform, pubescent ebracteate ; pedicles $\frac{1}{8}$-$\frac{3}{8}$ in. long. Calyx hairy ; tubes short, broadly campanulate, narrowed at the base, lobes $\frac{1}{4}$ in. long, lanceolate, acute. Corolla pale yellow ; segments obovate, obtuse, $\frac{3}{8}$-$\frac{1}{2}$ in. long. Stamens 2 ; filaments very short, thick flattened ; anthers $\frac{1}{12}$ in. long, one 2-partite, the other 3-partite, the cells conduplicate, the connective broad. *Female flowers* : peduncles $\frac{3}{4}$-$1\frac{1}{2}$ in. long, slender, ebracteate, ovary fusiform, beaked ; style stout ; stigmas 2, spreading, 2-partite. Fruit $\frac{3}{4}$-1 in. long, pyriform or broadly fusiform, narrowed into the curved peduncle, fleshy, dark green, 8-ribbed, sparsely hairy. Seeds $\frac{1}{6}$-$\frac{1}{4}$ in. long, broadly ovoid, slightly compressed, strophiolate, not margined ; testa polished and shining, dark brown.

Flowers June to July.

Habitat

Deccan Peninsula, Wight ; Mysore, Hyne ; Konkan, Stock. Distrib.—Tropical Africa.

Medicinal use

*Dymock** writes " The whole plant is acrid ; it is mentioned that a number of tubers were forwarded to the Chemical Analyser to Government from Satara as having been found in the possession of a person suspected of administering drugs to procure abortion. My specimen was grown from one of these tubers, which still retains vitality. *Dr. Lyon*, the Chemical Analyser, informs me that on reference to the records of his office he finds that Kadavanchi tubers have been three times sent to him within the last four years, as having been used to procure abortion."

Occurrence

India Distrib.	**Sholapur district Bombay, Satara, Bombay ; Naraina S. M. Country ; Dharwar, Bombay, Woodrow ; Jaipur, Rajputana.**
Peninsular India	**Pemkacherla, 1,200 ft., Anantapur Dist. Madras July 1889, J. S. Gamble.**
Central India	**Guna, Isagar Dist., Gwalior 1867, Coll. G. King.**

10. Cucumis

Cucumis, Linn. Gen. (1737), p. 296 edit. 6, p. 508, spec. edit. 1, p. 1011, edit. 2, p. 1435 ; Reich. Gen. p. 504 ; Juss. Gen. p. 395 ; Neck. Elem. 1, p. 237 ; Lour. Fl. Cochinch. 2, p. 591 ; Schreib. Gen. 2, p. 663 ; Thunb. Prodr. pl. Cap. 1, p. 13, Fl. Cap. 1, p. 156 ; Vent, Tabl. 3, p. 515 ; DC. Fl. Franc. 3, p. 690 ; Willd. Spec. 4, p. 611 ; Lois. in Dict. sc. nat. 10, p. 226 ; Ser. in DC. Prodr. 3, p. 299 ; Roxb. Fl. Ind. 3, p. 719 ; Wight et Arn. Prodr. 1, p. 341 ; Spach, Veg. phan. 6, p. 205 ; Meisn. Gen. p. 127 (91) ; Endl. Gen. Pl. p. 938 ; Torr. et Gr., Fl. N.-Amer. 1, p. 543 ; Arn. in Hook. Journ. of Bot. 3, p. 278 ; Wight in Ann. and Mag. of Nat. H. 8, p. 270 ; Roem. Syn. fasc., 2, p. 15, 68 ; Miq. Fl. Ind. Bat. 1, parti, p. 670 ; Naud. in Ann. sc. nat. ser. 4, v. 11, p. 9 et v. 12, po. 108 ; Sond. in Harv. et Sond. Fl. Cap. 2, p. 494 ; Benth. et Hook. Gen. pl. 1, p. 826 ; Hook. f. in Oliv. Fl. trop. Afr. 2, p. 542 ; Boiss. Fl. Orient. 1, p. 758 ; Cogn. in Mart. Fl. Brass. fasc. 78, p. 15 ; Clarke in Hook. f., Fl. Brit. Ind, 2, p. 619. *Cucumis et Melo* Tourn. Inst. p. 104, tab. 31, 32 (1700) ; Adans. Fam. 2, p. 138.—Rigocarpus, Neck. Elem. *1*, p. 238 (1790).

* Dymock, W. (1885). *Materia Medica West India* 341

Annual herb with a perennial root, climbing or trailing, hispid or scabrous. Tendrils simple, sometimes stright and spinescent. Leaves entire or palmately 3-7-lobed or 5-angled. Flowers yellow, monoecious. Male flowers fascicled (rarely solitary). Calyx tube turbinate or campanulate; lobes 5, corolla subcampanulate, deeply 5-lobed or 5-partite. Stamens 3 free; filaments short; anthers free oblong, one 1-celled, the others 2-celled, the cells linear, straight, curved or flexuose, the connective produced above into a papillose appendage. Pollen smooth. Rudimentary ovary glanduliform. Female flowers solitary. Calyx and corolla as in the male. Rudimentary stamens o. Ovary ovoid or globose, 3-5-placentiferous; ovules many, horizontal; style short; stigmas 3, obtuse. Fruit fleshy or corky, globose or cylindric terete or obtusely 4-angled, smooth or echinate, indehiscent, or 3-valved and tardily dehiscent. Seeds numerous, oblong, compressed, usually smooth. Dist. Tropical Asia and Africa, a few in Australia and America; species 26.

KEY TO THE SPECIES

A. Fruit smooth, glabrous or pubescent
- B. Perennial; leaves deeply cut into 5-7 obtuse lobes, scabrid . . . 1. *C. trigonus*
- BB. Annual; leaves usually 5-angled softly hairy, spherical ovoid elongated or contorted . . . . 2. *C. Melo.*
- BBB. Annual; 5 angular or slightly lobed, hispidulous, fruit glabrous sometimes tuberculated commonly elongate . . . . . 3. *C. sativus*

AA. Fruit echinate . . . . 4. *C. propheterum.*

1. ***Cucumis trigonus*** Roxb. Hort. Beng. 70; W. & A. Prodr. 342; Wight Ic. t. 497; Wight Ill. t. 105; Boiss. Fl. Orient. ii, 758; Dalz. and Gibs. Bomb. Fl. 103; Naud. in Ann. Sc. Nat. Ser. 4, xi, 30; *C. turbinatus* Roxb. Fl. Ind. iii 723; Miq. Fl. Ind. Bat. i, pt. i, 671; *C. maderaspetanus* Roxb. l.c. Wall. Cat. 6734; *C. Melo.* var. *agrestis* Naud. l.c. 73; *C. pubescens* Wall. Cat. 6729; Royle Ill. t. 47; *C. pseudo-colocynthis* Royle, Ill. t. 47; *C. eriocarpus* Boiss. Diagn. ii 59; *Bryonia. callosa* Herb. Rottler; F.B.I. v, 2, p. 619; Woodr. in Journ. Bomb. Nat. v. ii (1898) p. 640; Watt. Dict. Econ. Prod. v. 2, p. 635.

Perennial, scabrid, monœcious; stems 3-5 ft. long, slender, angled, rough with short rigid hairs Tendrils simple. Leaves sub-orbicular in outline, 1-2 in. long and broad (sometimes larger), scabrid on both surfaces, hispid on the nerves beneath, cordate at the base, deeply palmately 5-7-lobed, the lobes ovate oblong or obovate, often narrowed at the base, rounded at the apex, lobulate or dentate; petioles slender, striate, scabrid, often hispid $\frac{1}{2}$ to 2 in. long. *Male flowers*: peduncles slender $\frac{1}{5}$-$\frac{3}{8}$ in. long, in small clusters (rarely solitary). Calyx narrowly campanulate, hairy: tube $\frac{1}{8}$-$\frac{1}{6}$ in. long; teeth short, subulate. Corolla yellow, $\frac{1}{6}$-$\frac{1}{4}$ in. long; more or less pubescent; segments elliptic, acute. Appendage of the connective of the anthers a little shorter than the anthers. *Female flowers*: peduncles slender $\frac{1}{2}$-1 in. long in fruit. Ovary hairy. Fruit ellipsoid or sub-globose, when young strongly echinate gradually becoming smooth at maturity, $1\frac{1}{2}$ by $1\frac{1}{4}$ in. In Bombay districts, 2-$2\frac{1}{2}'' \times 1\frac{1}{2}''$-$2''$; longitudinally veriegated with 10 green stripes, pale yellow when ripe with bitter pulp. Seeds white ellipsoide, not margined.

Flowers June to October.

Habitat

Throughout India, Distributed to Malaya, North Australia, Afghanistan, Persia. The mountain tracts of Coromandel. Central Bengal, Central Provinces and the Punjab.

Occurrence

Central India	Indore 30-8-18, Coll. P. Mukerjee; Sagor
Wall. Cat.	Royal Botanic Garden, Calcutta 6734 D
Pen. India	Madras; Yettanhatti 1,000 ft., Bellary, July 1885, Coll. G. S. Gamble; Kalija, Chilka Lake, Ganjam Dt., 10 August 1913, Coll. D. Hooper; Thana, Bombay Nov. 23, 1898, Coll. G. M. Ryan; Coimbatore 1,000 ft., 5th April 1870, Coll. C. B. Clarke; Shevaroi Hills, S. India; Mettupellaym, 1,100 ft., Combatore Dist., 4-8-1910, Coll. C. E. C. Fischer; Sind; Sewnen Fort, 1878, Bombay Coll. W. Dalzell; Devarapalli 500 ft., Rampa Dist., Coll. V. Narayanaswami.
N. W. Himalaya	Dehra Dun, 1869, Coll. G. King
Bengal	Matla, Oct. 1898, Coll. Shaik Mokim; Bengal, Coll. S. Kurz.

2. ***Cucumis Melo*** Linn. Sp. Pl. 1753, 1011; Roxb. Fl. Ind. iii 720; Wall. Cat. 6738; W. & A. Prodr. 341; Jacq. Monog. du Melon t. 1-33; *C. utilissima* Roxb. l.c. 721; Wall. Cat. 6731: *C. flexusus* Linn.; *C. maculatus* Willd.; *C. Gurmia* and *C. Chata* Wall. Cat. 6726 ? and 6727; *C. cicatrisatus* Stocks. In Hook. Kew. Journ. Bot. iv. 148; Watt. Dict. Econ. Prodt. v. 2 p. 627; Cogniaux, in DC. Monogr. Phan v. 3 (1881) p. 483.

The sweet melon. Vern. Sans. *Karmuja;* Beng. *Kharmuj, phuti, kakur, bangi;* Hind. *Kharbuja, kharbuj;* Sant. *Tarbuj;* C.P. *Dungra;* Kangra *Kharbuza;* Bomb. *Kharbuja, kharbuj; chibuda;* Mar. *Chibunda;* Guz. *Tarbucha;* Sind *Gidhro;* Ladak. *Zaghum;* Afghan. *Sarda* or *sirda paliz;* Tam. *Vellari verai;* Tel. *Mulampunda:*

Annual, stem creeping, branched, obtusely angular with stiff (sometimes hooked) hairs on the ridges. Tendrils simple. Leaves 2-4 in. long and about as broad as long, acute, at the apex, cordate at the base more or less hairy on both sides, denticulate, usually 5-angled; petioles 1-1$\frac{1}{2}$ in. long, grooved and roughly hairy. *Male flowers* in axilary fascicles of about 2-3; peduncles $\frac{1}{4}$-$\frac{1}{2}$ in. long, very slender densely hairy. Calyx densely hairy; the tube narrowly campanulate, $\frac{1}{8}$-$\frac{1}{6}$ in. long; teeth $\frac{1}{10}$in. long, subulate, densely hairy. Corolla $\frac{1}{4}$-$\frac{3}{8}$ in. long, the segments hairy outside, often terminated by a hairy apiculation. *Female flowers*: calyx tube constricted above the ovary. Ovary ellipsoid, clothed with long bristly deciduous hairs. Fruit ellipsoid or turbinate, about 1$\frac{1}{2}$ in. long, smooth or with a few small bristles. Seeds numerous, narrowly ovoid, compressed smooth.

Flowers January to October.

There are several varieties differing in properties and in the size, shape and appearance of the fruit. Duthie and Fuller describe two varieties. Var. 1 *Momordica* and var. 2 *Utilissima* (Field and Garden Crops, 1882, tt. 53, 54). Var. *agrestis* is common in the neighbourhood of Bombay and on the Western Ghats.

Habitat

Cultivated throughout India, especially in the sandy beds of rivers. Distributed through cultivation in most hot countries and according to Clarke it may be a cultivated form of *C. trigonus*. The origin of the plant is uncertain. M. de Candolle considers it to be probably a native of N. W. India, Baluchistan and perhaps tropical Africa.

Several cultivated varieties of this species are met with in India. It is difficult to enumerate all the varieties in absence of authentic specimens. The two predominating varieties, viz., (1) *momordica* (2) *utilissima* are given below. Var. *momordica.* The fruit is cylindrical, smooth, not fluted but it is frequently mottled. Two forms of this variety are readily recognised—the one grown in the rains and the other in the hot season. The fruit bursts spontaneously when ripe: it may grow upto 2 ft. in length and upto 6 inches in diameter. The seeds are smaller than the var. *proper.*

The seeds are used as a cooling medicine.

The fruit is much eaten by the Indians and the Europeans alike, when young they may be used as substitute of cucumber, when ripe, with the addition of a little sugar, they are scarcely inferior to the melon and reckoned very wholesome.

Cultivated here and there throughout India.

Var. *utilissima*: Beng. *Kakur* or *kankur, kakri.*

The fruit varies from short oval or cylindrical to elongate and is either straight or curved like some varieties of cucumber. The seeds are smaller and slender than melon proper. Cultivated in Bengal, the North-West Provinces and the Punjab during the hot weather and the rains.

The seeds of these useful species of cucumis are described as cooling, edible, nutritive, and diuretic, and are used in painful micturition and suppression of urine. Two drachms of seeds, rubbed into a pulp with water, are given alone or in combination with salt and Kanjika (U.C.Dutt). O'Shaughnessy* says "The powder of the toasted seed powerful diuretic, and serviceable in promoting the passage of sand or gravel".

* O'Shaughnessy (1841). *Bengal Dispensatory and Pharmacopœia*, 351.

Occurrence

Assam	Dhekia juli, April 1902, Coll. A. C. Chatterjee; Singrabari April 1902, Coll. A. C. Chatterjee; Dhubri, June 1902, Coll. A. C. Chatterjee; Margherita February 1902, Coll. A. C. Chatterjee; Gouhati north side of Brahmaputra, April 1902, Coll. A. C. Chatterjee; Orang, March 1902,Coll. A. C. Chatterjee; Mangaldai March 1902, Coll. A. C. Chatterjee; Nazira, July 1843;
Bengal	Howrah Dist., Sept. 1869; Coll. S. Kurz; Agartala 800-1,000 ft., Hill Tipperah 27-9-14, Coll. P. M. Debbarman;
Burma	Pegu, Coll. S. Kurz; Pagan, 3-1-68, Coll. Anderson; opposite Minbu town 8th March 1903, Coll. Aubert & Ghose.

3. ***Cucumis sativus*** Linn. Sp. Pl. 1012; Lamk. Ill. t. 795; Roxb. Fl. Ind. iii 72; Wall. Cat. 6737; W. & A. Prodr. 342; Miq. Fl. Ind. Bat. i. pt. i, 671; Naud. in Ann. Sc. Nat. Ser. 4, xi, 27; Kurz. in Journ. As. Soc. 1877, pt. ii, 103; *C. muricata* Wall. Cat. 6735 A; *C. Hardwickii* Royle Ill. t. 47.

The cucumber. Vern. Sans. *Sukasa, Trupusha;* Hind. *Khira;* Beng. *Sasa, khira;* Orissa *Kakai;* Pb. *Khira, khiyar;* Simla *Kakri;* Bomb. *Kakri;* Mar. *Kakdi*; Tam. *Mulevekri;* Tel. *Doza-koia*; Kan. *Santa kayi.*

Stems scabrous. Leaves ovate 5-angular or slightly lobed, lobes acute hispidulous on both surfaces and also often with soft hairs, 3-5 in. diam. petiole 2-3 in. Female peduncles sometime 2, petals $\frac{3}{8}$ in. young ovary muricate with rigid prickles. Fruit glabrous sometimes tuberculated commonly elongate, 12 by $1\frac{1}{2}$ in.

Habitat

Throughout India, cultivated. Distributed in all the warm and warm-temperate countries, cultivated. Wild not known.

There are two primary varieties of this species, one a creeping plant cultivated in the fields during the hot season and the other a climber cultivated near the homesteads during the rains. The hot weather variety bears small egg shapped fruit, which is generally greenish or blackish in colour. It is sown in February to March in any soil, preferably a rich one. This is the proper *khira* or *khirai* of East Bengal. The fruits are smaller, thicker, globuler or bluntly triangular.

The rainy season variety has much larger fruits. There are two forms of this variety, the one having dark green fruits and the other of creamy white colour; both when full grown turn rusty brown. The rainy season variety is the most common and is universally eaten by people of all classes. Both these varieties are eaten raw but the latter variety with cylindric fruits are generally used in the curry.

Medicinal use

The leaves. boiled and mixed with cum in seeds, roasted and powdered, are administered in the throat affections. Powdered and mixed with sugar they are also powerfully diuretic and are sold in the bazars of Upper India.

" In sunstroke, pieces of cucumber are put on the bed so that the patient may breathe moistened air in order to nutralize the heat of the body " (A Surgeon).

The seeds yield an oil.

Occurence

Assam	Sadiya August 1909, Lakhimpur, Coll. R. K. Das; Nowjan 400 ft., Naga Hills, 14. Oct. 1885, Coll. C. B. Clarke
N. W. Himalaya	N. W. India;
Wall. Cat.	Kenvarikot, 24. April 1809, 6737 B
Bengal	S. Kurz; Agartala 600-800 ft., Hill Tipperah Sept. 1915, Coll. P. M. Debbarman; Royal Botanic Garden, Calcutta Bamunpukri 30-7-76
Burma	Pegu February 1901, Coll. S. Kurz
Laccadives	Kiltan, 1891, Coll. H. N. I.M. " Investigator "
Sikkim	Kalimpong 4,000 ft., Darjeeling 9. Dec. 1879, Coll. G. S. Gamble; Sal Forest 1879, Coll. G. King
Pen. India	Chintagandi Hill near Marudumalli, 1,000 ft. Rampa District, 30-9-20, Madras Presidency, Coll. V. Narayanaswami
Central India	Abux, 1868

4. ***Cucumis prophetarum*** Linn. Cent. i. 32; Wall. Cat. 6733; W. & A. Prodr. iii. 342; Boiss. Fl. Orient. ii. 758; Naud. in Ann. Sc. Nat. Ser. 4, xi, 14; F. B. I. v. 2, p. 619; Woodr. in Journ. Bomb. Nat. v. ii (1898) p. 640.

Monoecious. Stem slender, branched, angled and grooved, scabrid. Tendrils very short, striate, sometimes o. Leaves polymorphous, rigid $\frac{3}{4}$-2 in. long and broad, somewhat ash coloured, scabrid, coarsely hairy on the nerves beneath, cordate or truncate at the base, frequently 3-lobed, the lobes often lobulate with rounded apices, the terminal lobe often contracted at the base; nerves prominent beneath; petioles $\frac{1}{2}$-1 in. long. *Male flowers* solitary or fascicled; peduncles filiform densely hairy, $\frac{1}{20}$-$\frac{1}{4}$ in. long. Calyx tube subcylindric, $\frac{1}{6}$ in. long; segments ovate oblong, subacute. Filaments filiform, slightly hairy; anthers oblong, the appendage of the connective slightly dilated at the apex. *Female flowers*: peduncles (in fruit) stout, $\frac{1}{2}$-1 in. long. Fruit subglobose 1-1$\frac{1}{2}$ in. long and nearly as broad, longitudinally striped with green and white, echinate, the spines not or scarcely pungent, $\frac{1}{20}$-$\frac{1}{8}$ in. long. Seeds ellipsoid, not margined, $\frac{1}{6}$ in. long.

Flowers July to August.

Habitat

In Bombay Presidency, it is confined to Sind. Distributed to Baluchistan, Arabia, Tropical Africa to Guinea.

Occurrence

Bombay	Landhi, Karachi, Sind, 13th August, 1912, Coll. D. Hooper; Sind, Coll. J. E. Stocks

11. Citrullus

Citrullus, Neck. Elem. 1, p. 240 (1790); Schrad. in Eckl. et Zeyh. Enum. pl. Afr. austr. 2, p. 279 et in Linnaea, 12, p. 412; Meisn. Gen, p. 126 (91); Spach. veg. phan. 6, 212; Endl. Gen. p. 937; Roem. Syn. fasc. 2, p. 12, 49; Webb et Berth. Phyt. Canar. 2, p. 3; Miq. Fl. Ind. Bat. part 1. p. 661; Naud. in Ann. sc. nat. ser. 4, v. 12, p. 99; Benth. et Hook. Gen. 1, p. 826; Hook. f. in Oliv. Fl. trop. Afr. 2, p. 548; Cogn. in Mart. Fl. Bras, fasc. 78, p. 18; Clarke in Hook. f. Fl. Brit. Ind. ii, p. 620.—*Colocynthis* Tourn. Instit. p. 107.—*Cucurbitae et Cucumeris spec.* Auct.

Perennial herbs usually trailing. Tendrils 2-3-fid, rarely undivided. Leaves deeply 3-7-lobed, the lobes usually lobulate. Flowers rather large, yellow, monoecious, all solitary. *Male flowers*: calyx tube broadly campanulate; lobes 5. Corolla 5-partite beyond the middle, sub-campanulate; segments oblong ovate, obtuse, Stamens 3; filaments short, free; anthers scarcely cohering, one 1-celled, the other 2-celled, the cells linear, flexuose, the connective not produced. Pollen smooth. Rudimentary ovary glanduliform. *Female flowers:* calyx and corolla as in the male. Rudimentary stamens 3, setose or ligulate. Ovary ovoid, 3-placentiferous; ovules many, horizontal; style short; stigma 3, thick, reniform. Fruit globose or ellipsoid, smooth, fleshy, indehiscent.—Seeds very many, much compressed, smooth. Distributed to the Eastern Mediterranean region, Tropical Africa, Western Asia. Species 3.

Key to the species

Leaves hoarsely scabrid; fruit globose small	1. *C. colocynthis*
Leaves glabrous or somewhat hairy, hardly scabrid; fruit generally larger	2. *C. vulgaris.*

1. ***Citrullus Colocynthis*** (Linn) Schrad. in Linnaea xii (1838) 414; Arn. in Hook. Journal Bot. iii, 276; Wight Ic. t. 498; Miq. Fl. Ind. Bat. i. pt. i. 662; Naud. in Ann. Sc. Nat. ser. 4. vol. xii, 99; Dalz. & Gibs. Bomb. Fl. 101; Boiss Fl. Orient. ii 759; *Cucumis colocynthis* Linn: DC. Prodr. iii. 302; Roxb. Fl. Ind. iii. 719; Wall. Cat. 6732; W. & A. Prodr. iii. 342; Woodr. in Journ. Bomb. Nat. v. ii (1898) p. 640; F.B.I. ii. p. 619; Watt. Dict. Econ. Prod. v. 2, p. 635.

Colocynth. Vern. Sans. *Indravaruni, vishala, indralvaruni, makhal*; Hind. *Indrayan, makal*; Beng. *Makal, indrayan*; Pb. *Indrannmaraghune, kartuma, ghurumba, kurtanmae, tumbi, ghorumba,*

vishlumba (*nanzal* and *indrayan* fruit; *tukkhm* and *tumna* seeds); Sind. *Tru-jo-gosht, tru-jo-par;* Guj. *Truna deda, tras, indravana, indravena, indrak;* Bomb. *Indrayan;* Mar. *Indrayan indravana; kadu vrindavana, thorli indrayan;* Tam. *Paycumuti, pey-ko-mattimmatti, peyt-tumatti, verit-tumatti,* Tel. *Pusta, kaya-choythupusta*; Kan. *Tumti kayi.*

Monoecious; root perennial; stems diffuse or creeping, slender, angled, branched, hirsute or scabrid. Tendrils simple or 2-fid, slender, hairy. Leaves very variable $1\frac{1}{2}$-$2\frac{1}{2}$ by 1-2 in. in the wild form (larger in the cultivated one), usually deltoid in outline, pale green above ashy beneath, scabrid on both surfaces, 5-7-lobed or very commonly 3-lobed, the middle lobe the largest, each lobe deeply pinnatifid or sinuate lobulate, the segments obtuse; petioles $\frac{1}{2}$-1 in. (larger in the cultivated form) densely hirsute. *Male flowers*: peduncles $\frac{1}{4}$-$\frac{1}{2}$ in. long, villous. Calyx hairy, campanulate, $\frac{1}{4}$ in. long; teeth lanceolate, $\frac{1}{12}$ in. long. Corolla $\frac{1}{4}$ in. long, pale yellow; segments obovate, apiculate. *Female flowers*: ovary ellipsoid, densely hairy. Fruit globular slightly depressed, 2-3 in. in diam., variegated green or white, glabrous when ripe filled with a dry spongy vety bitter pulp; epicarp thin. Seeds $\frac{1}{6}$-$\frac{1}{4}$ in. long, pale brown.

Flowers November to January.

Habitat

Throughout India, cultivated and very often apparently wild. Distributed to Western Asia, Arabia, all over Africa except the Cape, Spain.

Medicinal use

The Pharmacopœia of India describes colocynth as a hydragogue cathartic, useful in constipation, hepatic and visceral congestions, dropsical affections, and other cases requiring purgatives. Sanskrit writers describe the fruit as "bitter, acrid, cathartic and useful in jaundice, ascitis, enlargement of the abdominal viscera, urinary diseases, rheumatism etc. An oil prepared from the seeds of Indian cylocynth is used for blackening grey hairs. A poultice of the root is said to be useful in inflammation of the breasts (U. C. Dutt, Mat. Med. Hind.). According to the Muhammadan writers, colocynth is a drastic purgative, which removes phlegm from all parts of the system. They recommend the fruit, leaves and root in costiveness, dropsy, jaundice, colic, worms, elephantiasis etc. It acts as an irritant on the uterus, and its fumigation brings on the menstrual flow. The author of the Makhzan describes a curious mode of administration. "A small hole is made at one end of the fruit and peeper-corns are introduced; the hole is then closed, the fruit enveloped in a coating of clay and buried in the hot ashes near the fire place for some days; the pepper is then removed and used as a carminative aperient. Similar preparation is made with rhubaub root instead of pepper" (Dymock, *Meteria Medica West Ind.*). Murray* in his *Apparatus Medicaminum*, recommends the use of tincture of colocynth in cases of gout, rheumatism, violent headaches and palsy, in doses of fifteen drops, morning and evening. Dr. Kirkpatrick states that the rind with rhuburb is used by the native practitioners in supression or repression of urine. Colocynth is rarely employed alone, it is generally given in combination with other purgatives and carminatives. It commonly causes griping when used alone; in excessive doses it produces inflammation of the intestines and even death. The principal efficient forms for the use of this drug are the compound extract of colocynth, compound colocynth pill and colocynth and henbane pill (Bently and Trim. Med. Pb. 114). From the pulp of this fruit a watery extract is prepared, which is much employed as a purgative in the form of pills.

According to Dalzell and Gibson† a compound extract of colocynth is prepared in large quantities at Hewra, for the supply of the medical stores. In the Punjab the fruit is extensively employed as purgative for horses. The pulp of the fresh fruit mixed with warm water, or the dried pulp with ajwan, is reckoned as a special remedy in cholera. The dried root reduced to powder is given as a purgative (Bellew in Watt's *Dictionary of Economic Products*). Stocks says the root and the juice are both used medicinally in Sind. In a report of the drug shown at the late colonial and Indian exhibition from Baroda, the properties of the fruit and root are given in very nearly the same terms

* Murray, J. A. (1881). *Plants and Drugs of Sind*, 39
† Dalzell, N. A. and Gibson, A. (1861). *The Bombay Flora*, 101

as above. So that the knowledge of this drug seems very extensively diffused over India. "Used in dropsy and amenorrhœa" (T. Ruthnam, Madras). "First rate medicine in asthma" (V. Ummegudien, Mettapollian, Madras).

Act. Prin.: Bitter substance,: Colocynthin, Colocynthetin.

Official preparation—Extract of colocynth, dose ½ grain; compound extract of colocynth—dose 4 grains.

Peninsular India	Bodinayakanur, Madura Dist., Madras, December 1910, Coll. A. Meebold; Bukkapatam 2,000 ft., Anantapur District, Madras, July 1884, Coll. J. S. Gamble; Tirukarnugudi Tinnevelly Dt., Madras 11th February 1913, Coll. D. Hooper and M. S. Ramaswami; Nandavaram, Nellore Dist., 24. July, 1914, Coll. M. S. Ramaswami
N. W. Himalaya	Sutlej valley, Kumharsain (Punjab States), Kulu and Kangra, 3,500 ft. Punjab 26th September, 1894, Coll. Reporter on Economic Products to the Govt. of India; Punjab 1,000 ft., Coll. T. Thomson; Afghanistan & Northern Baluchistan Coll. T. E. T. Aitchison
Baluchistan	Nal. Kalat Beluchistan, 1877, Coll. O. T. Duke; Kacha Daman, Kalat, 5,000 ft., 28th July 1912, Coll. A. Watson; *Makai ?* 3,000 ft., 22nd August 1912, Coll. A. Watson; Karwa Tu (Sind); Mir Ali Khel, 3,600 ft., 18-5-96, Coll. Harsukeh; Banks of Jamna 2nd July 1813, 6732 B, Wall. Cat.; Nilikach 1,500 ft., 23-5-95, Waziristan. Coll. Harsukeh; Lar Koh 3-4,000 ft., Sept. 1912, Coll. Lieut. G. E. Everett.

2. ***Citrullus vulgaris*** Schrad. ex Eckl. & Zeyh. Enum. 279; Naud. in Ann. Sc. Nat. ser. 4, xi, 100; Dalz. & Gibs. Bomb. Fl. 102; Kurz. in Journ. As. Soc. 1877, pt. ii, 103; C. fistulosus stocks in Hook. Kew Journ. Bot. iii, t. 3; *Cucumis citrullus* DC. Prodr. iii, 301; *Cucurbita citrullus* Linn. Roxb. Fl. Ind. iii, 729; Wall. Cat. 6717; W. & A. Prodr. 351; Watt. Dict. Edcon. Prod. v. ii, p. 331, and Woodr. Gard. in Ind. ed. 5, p. 331.

The water melon. Vern. Sans. *Taramburja, chayapula;* Hind. *Turbuza, tarbuz, tarmuz, karbuz, habinda, hindwana, samanka;* Beng. *Tarbuza, tarmuj;* Pb. *Tarbuz, mathira, nindal;* Sind. *Karigo, chanho, meho;* Guj. *Tarbuch, turbuch, karinja;* Bomb. *Turbuj, kabingad, kalinga, pharai,* Mar. *Tarbuj, Kalingada;* Tam. *Pitcha, pullum.*

A climbing or trailing, hispid annual. Stems branching, angular; tendrils 2-fid, firm; pubescent. Petioles about 2 in. nearly round, villous; blade of leaf 3-5 in. long by 2-3 in. broad, triangular ovate, cordate, deeply trified; segments pinnatifid, terminal one larger; lobes undulate or lobulate, pale green above, ashy beneath. Flowers monoecious, axillary, solitary, rather large. *Male flowers*: peduncle shorter than the petiole; calyx campanulate, lobes narrowly lanceolate. Corolla about an inch in diam., greenish outside and villous; segments ovate, oblong, obtuse, 5-nerved, stamens 3, anthers free. *Female flowers:* calyx tube fused with the ovary, contracted above, lobes and corolla as in the male; ovary ovoid; densely villous; style short, stigmas 3. Fruit large, ovoid, pale or dark green or mottled, some times covered with a glacous waxy bloom; flesh white, yellowish or red, at times deeply pink. Seeds compressed, and usually margined, varying much in shap and colour. Some of the verieties grown in Alibay in the Kolaba District, have glacous green globose fruits.

Var. *fistulosus* Stocks Squash melon. Punjab. *Tinda,* has thick steams, leaves sparingly lobed, and is plentifully supplied with long somewhat hispid hairs. The fruits are almost round and are of the size of a criket ball with sparingly spinous hairs on the surface. Used in vegetable before it is full grown. Cultivated in North India.

Habitat

Cultivated throughout India. Distributed through cultivation in all warm countries of the world.

The wild plant may be either bitter or sweet without any observable structural differences. The bitter form comes very close to *C. colocynthis*, when that species is cultivated (Watt). Cultivated throughout India.

Linnaeus believed it to be a native of Southern Italy, while Seringe supposed it to be indigenous to India and Africa. It was afterwards discovered that it grew wild in Tropical Africa. "Livingstone

saw districts literally covered with it, and the savages and several kinds of wild animals eagerly devoured the wild fruit." It was cultivated by the ancient Egyptians, as appears from their paintings. The chinese only received the plant in the tenth century of the Christian era (DC., Orig. Cult. Pl. 263).

Medicinal and other uses

The seeds are used as a cooling medicine. Dymock* says that they are in great demand and kept decorticated and ready for use. In Bombay they are considered cooling, diuretic, and strengthening, and are sold in the bazars along with other cucurbitaceous seeds. Ainslie† remarks that the vytians prescribe the juice of the fruit to general thirst, and also as an anticeptic in typhus fever, in which cases he himself administered it with good results.

"Cooling as well as a diuretic" (Asst. Surgeon Ananda Chandra Mukerjee, Noakhali).

Oil: The seeds yield a clear, bland, pale coloured, limpid oil, used for burning the lamps, and probably also as an edible oil (Watt's *Dict. Econ. Products*).

The fruit is wildly used by all classes of Indians as a cooling sweet drink during the summer to quench thirst. *Tinda* (*C. vulgaris*, var. *fistulosa*) is a common vegetable in Northern India.

Occurrence

Peninsular India	Mysore and Carnatic (cultivated), Coll. G. Thomson; Trichonopoly, 3rd September 1878, Coll. G. King
Punjab	Amritsar, June 1855
N.W.P.	Banda (cultivated) 17th May 1901, Coll. Mrs. A. S. Bell
Bihar	Pukhuria, Manbhum, Coll. Rev. A. C. Campbell
Bengal	Dacca, 16th June 1872, Coll. C. B. Clarke; Agartala 300 ft. Hill Tipperah, April 1921, Coll. P. M. Debbarman; Coll. S. Kurz; Harinkhola, Jahanabad, 12th March 1902, Coll. J. D. Naskar; Goghat, Hughly Dist., August 1902, Coll. A Hossain Dingra Ghat, 29th August 1877, Coll. G. King; Royal Botanic Garden, Calcutta
Burma	Kamamoung, Salween, June 1912 Coll. A. Meebold; opposit Minbu town, 8th March 1903, Minbu District, Coll. Gage; Sujin, August 1891, Coll. Abdu Huk
Gangetic Plain	Gorakhpur 2-5-98
N. India	Multan, Bombay, Coll. Dalzell
Assam	Dhubri, February 1902, Coll. A. C. Chatterjee
Pen. India	Karachi, 1st May 1913 (var. fistulosus)

12. Coccinia

Coccinia Wight & Ern. Prodr. (1834) p. 347. *Cephalandra* Schrad. in Eckl. & Zeyh. Enum. Pl. Agr. Austr. (1836) p. 280.

Slender scandent or prostrate herbs, root often tuberous. Tendrils slender simple. Leaves petiolate, deltoid, or subrotund, angled or lobed, sometimes glandular beneath. Flowers rather large, white or yellow dioecious. *Male flowers* solitary, or sub-corymbose at the apex of a peduncle. Calyx short, campanulate or turbinate; limb 5 lobed. Corolla campanulate, shortly 5-fid. Stamens 3; filaments connate into a column. rarely free; anthers connate into a capitulum or cohering, the cells conduplicate. Rudimentary ovary o. *Female flowers* solitary. Calyx and corolla as in the male. Rudimentary stamen 3, bifid. Fruit baccate, ovoid or ellipsoid, indehiscent. Seeds many, ovoid compressed, margined; testa smooth or scrobiculate. Distributed to tropical Asia, tropical and south Africa; species 13.

This genus was established as *Coccinia* by Wight and Arnott in 1834 two years prior to the publication of the genus as Cephalandra by Schrader (1836).

Coccinia indica (Naud) Wight & Arn. Prodr. 1834, p. 347; *Cephalandra indica* Naud. in Ann. Sc. Nat. Ser. 5, v. 16; Kurz. in Journ. As. Soc. 1877, pt. ii, 103; *Momordica monadelpha* Roxb. Fl. Ind. iii 708; *Byronia grandis* Linn. f. Suppl. 126; Wall. Cat. 6700, except D, I, K. L; *Bryonia*

* Dymock, W. (1885). *Materia Medica W. India*, 289
† Ainslie, W. (1826). *Materia Medica*, 217

palmata Wall. Cat. 6711 A, B, C; Wight Ill, t. 105; Dcne. in Jacq. Vog. Bot. t. 72; Hook. Ic. Pl. t. 138; Miq. Fl. Ind. Bat. i. pt. i. 673; Dalz. & Gibs. Bomb. Fl. 103; C. schimperi, Naud l.c. Ser. 4, xii, 16; *C. Wightiana* Roem. Synops. ii 93; Miq. 1. c. 674 Rheede Hort. Mal. vii. 6. 14; Woodr. in Journ. Bomb. Nat. v. ii (1898) p. 640; Watt. Dict. Econ. Prod. v. 2, p. 252; *Bryonia cordifolia* Linn. Sp. Pl. (1753) p. 1012; *Coccinia cordifolia*, Coginaux in DC. Monogr. Phan. v. 3, (1881) p. 529.

Vern.: Sans. *Bimba* (or *vimba*), *bimbika*; Hind. *Bhimb, kandurikibel* or *kanduri*; Pb. *Kanduri, ghol kundru*; Beng. *Telakucha, bimba*; Sind *Golaru, kanduri*; Guj. *Phobe, gluru, galedu*; Bomb. *Tendli, rantondla, teaduli, bhimb*; Mar. *Zidadi, tendli, tondali, bimbi*; Tam. *Kovai, kioc, kwai*; Tel. *Donda, bimbika, kankidonda, kaidonda*; Mala. *Kwelkooa*; Kan. *Tondeballi.*

Perennial, scandent or prostrate, much branched; root thick; stem grooved, slender, glabrous; tendrils slender, striate, simple. Leaves 2-4 in. long and broad, bright green above, pale beneath, studed and sometimes rough with papillae, palmately 5-nerved, from a cordate base, with globular shining glands in between the main nerves principally towards the basal side of the blade obtuse 5-angled or sometimes deeply 5-lobed, the lobes broad, obtuse or acute, epiculate, more or less sinuate toothed; the principal teeth always ended in a specialised brown point; petiole $\frac{3}{4}$—$1\frac{1}{4}$ in. long. *Male flowers:* peduncles 1-flowered, $\frac{3}{4}$—$1\frac{1}{2}$ in. long, subfiliform. Calyx tube glabrous, broadly campanulate $\frac{1}{6}$—$\frac{1}{5}$ in. long; teeth 1 10 in. long, linear. Corolla 1 in. long, triangular, acute staminal column glabrous; capitulum of anthers sub-globose. *Female flowers:* peduncles $\frac{1}{2}$—1 in. long. Staminodes 3, subulate, $\frac{1}{8}$ in. long. Ovary fusiform, glabrous, slightly ribbed. Fruit fusiform-ellipsoid, slightly beaked, 1—2 by $\frac{1}{2}$—1 in., marked when immature with white streaks, bright scarlet when fully ripe. Seeds somewhat obovoid, rounded at the apex, slightly papillose, much compressed, yellowish grey. Flowers August to September.

Habitat

Throughout India, common, sometimes cultivated. Distributed to Malaya and Africa.

The anatomical study of the leaves reveals the presence of innumerable deposit of calcium carbonate on the upper epidermal cells. These cells are completely or partially imbeded with the salt, exhibiting dotted appearance on the leaf surface. A number of small shining glands are present on the lower surface of the leaf at the basal region on the blade on both sides of the mid rib. These glands secrete sugary solution particularly through the superficial tissue into the reserve tissue which finally escapes out of the body surface. The tracheidal ends are the channels through which the liquid is carried into the gland or extranuptial nectaries [Chakravarty (1937) Physiological Anatomy of the Cucurbitaceae, *Philipp. J. Sci.* 63, (4), 111 and 112].

Medicinal and other uses

" The expressed juice of the thick tap-root of this plant is used by the leading native Kavirajes as an adjunct to the metalic preparations prescribed by them in diabetes.". " The expressed juice is directed to be taken in doses of one tola along with a pill, every morning " (U.C. Dutt, *Materia Medica Hind.*). The root according to Moodeen Sheriff,* is sold as a substitute for *Kabar* (*Capparis spinosa* root) in the bazars of Southern India. The leaves are of deep green colour, and are useful as a colouring agent in preparing several ointment from the essential oil. ' The root when cut exudes a somewhat sticky juice, which hardens into reddish green on drying, as is very astringent, but not bitter like the fruit ' (Dymock)†. The bark of the root, dried and reduced to powder, is said to act as a good cathartic, in a dose of 30 grains. The leaves mixed with ghee, are applied as a liniment to sores. The whole plant bruised and mixed with the oil of *Euphorbia neriifolia* and powdered cumin seeds, is administered by natives in special diseases. The leaves are applied externally in eruptions of the skin, and the plant internally in gonorrhoea. In the Konkan the green fruit is chewed to cure sores on the tongue (ex D.E.P).

The fruit is eaten both raw and cooked. It is eaten fresh when ripe and cooked in curries when green.

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* Sheriff Moodeen (1869). *Supplement to the Pharmacopoeia of India,* 110

† Dymock, W. (1885). *Meteria Medica West India,* 351

Occurrence

Himalaya N.W. . . .	Tehri Garwal U. P. 30-9-01, Coll. Mackinon
Peninsular India . . .	Kota, Rampa country Nellor Dist., Madras, 8-10-1920, Coll. V. Narayanaswami; Quilon Travancore, 17-8-13, Coll. M. Rama Rao; Courtallum Travancore, 29-11-13, Coll. M. Rama Rao; Lower Palni Hills 1,600 ft., May, Coll. Rev. G. Rodriguez; Coimbatore 1,400, 10-7-1911, Coll. C.E.C. Fischer; Mount. Nilgiri and Coorg, Coll. G. Thomson; Triplicane, Madras, February 1876; Shevaroy Hills, Salem Dist., Coll. Perrottet; Cape Comorin, Travancore, 21-10-93, Coll. M. A. Lawson; Giriki kandia 1,000 ft., 4-8-1905, Coll. C.E.C. Fischer; Mudumadugu 500 ft., Cuddapa District, February 1883, Coll. G. S. Gamble; Sriharikota, Nellore District, August 1883, Coll. J. S. Gamble; Tirukarungudi, Tinnevelly District 11th February 1913, Coll. D. Hooper & M. S. Ramaswami; Papanasam to Mundandurai, Tinnevelly District, 18th February 1913, D. Hooper & M. S. Ramaswami; Bahegaon, Chilka lake, Ganjam District 8th August, Coll. D. Hooper; Colombo 1860
Burma	Pwinbya, Minbu Dist., September 1902, Coll. Shaik Mokim; Fort Stedman Yawng-hwe, 1893, Coll. Abdul Khalil; Inle Lake, Yawng-hwe Southern Shan States, February 1917, Coll. N. Annandale; Pakokku, 19th August 1909, Coll. J. H. Lace
W. India	Badami Bijapur Dist., Bombay 1892; Andra, August 1868; Cutch, Coll. Dr. Stoliczku; Mahabaleshwar 4,500 ft., Satara Dist. Bombay 20th Sept. 1900, Coll. D. Hooper
Bengal	Agartala 500-1,000 ft., Hill Tipperah, Coll. P. M. Debbarman; Goghat Hughly District, August 1902, Coll. A. Hosain; Sundriban, August 1902, Coll. D. Prain; Sundriban 21-2-1900, Coll. Janardan; Banks of river Karnaphuli below Rangamati Chittagong District, 19th March 1899, Coll. A. T. Gage; S. Kurz; Sibpur, Coll. S. Kurz; Botanic Garden
Bihar	Singbhum 26th November 1902, Coll. H. H. Haines;
Gangetic Plain	Banda U. P. 10th May 1901, Mrs. A. S. Bell; Gangetic plain Coll. T. T.; Gorakhpur 17-6-98; Gorakhpur U. P. 11-5-98, Coll. Inyet
Laccadives Isls . . .	Aucutta, Nov. 1891, Coll. H. M. I. M. Investigator
Malay Peninsula . . .	Batu Gaja jungles, 17-11-1900, Coll. E. Deschamps
Wall. Cat.	Sylhet, 6700 G; H.B.C. 6700 F, 6700 B; 6700 C or E; 6700 H;
Sind	Landli Karachi 13th Aug. 1913, Coll. D. Hooper.

13. Cucurbita

Cucurbita, Linn. Gen. edit. 1, p. 297 (1737), edit. 6, p. 507, Spec. edit. 1, p. 1010, edit. 2, p. 1434 Reich. Gen. p. 504; Duch. in Lam. Encycl. meth. Bot. 2, p. 148; Juss. Gen. p. 396; Schreb. Gen. 2, p. 622; Willd. Spec. 4, p. 606; Poir. in Dict. sc. nat. 11, p. 231; Ser. in DC. Prodr. 3, p. 316; Roxb. Fl. Ind. 3, p. 718; W. et Arn. Prodr. 1, p. 350; Spach. Veg. phan. 6, p. 197; Meisn. Gen. p. 127 (91); Endl. Gen. p. 928; Roem. Syn. fasc. 2, p. 16, 83; Ser. Fl. jard. et gr. cult. 2, p. 531; Miq. Fl. Ind. Bat. 1, part 1, p. 672; Naud. in Ann. sc. nat. ser. 4, v. 6, p. 5; Benth. et Hook. Gen. 1, p. 828; Hook. f. in Oliv. Fl. trop. Afr. 2, p. 555; Cogn. in Mart. Fl. Bras. fasc. 78, p. 19; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 621—*Pepo* Tourn. Inst. p. 105; Adans. Fam. 2, p. 138; Moench, Meth. p. 653.—*Melopepo* Tourn. l. c. p. 106—*Sphenantha* Schrad. in Linnaea, 12, p. 416; Arn. in Hook. Journ. of Bot. 3, p. 275; Wight in Ann. and Mag. of Nat. Hist. 8, p. 268; Meisn. Gen. Comm. p. 356; Roem. l. c. p. 102—*Pileocalyx*, Gaspar in Rend. del Acad. sc. di Napoli, 6, p. 409 et in Ann. sc. nat. ser. 3, v. 9, p. 220; Giorn. bot. Ital. 2, p. 242; Walp. Ann. 2, p. 647.—*Tristemon*, Scheele in Linnaea, 21, 1848 p. 586.

Large climbing herbs, hispid or hairy; tendrils 2-4-fid. Leaves petioled, cordate, ovate, 5-angularor lobed. The midrib of the leaf from the proximal part of the blade internally represents 9 vascular bundles arranged in an ellipse. Flowers monoecious, all solitary, yellow, very large. *Male:* calyx tube campanulate, lobes 5, linear or foliaceous; corolla campanulate, 5-lobed hardly half way down; Stamens 3, inserted in the calyx tube, anthers connate, one 1-celled, two 2-celled, cells conduplicate. *Female:* calyx and corolla as in the male; ovary oblong, style short, stigmas 3, bifid; ovules very many, horizontal; placentas 3. Fruit fleshy, indehiscent, often large. Seeds ovoid or oblong, compressed margined or not. Distrib. species 5, of which 4 are cultivated, one said to be wild in Africa.

A number of small club-shaped glands are present on the lower surface of the leaves. These glands arise from the leaf surface and not from the veins their anatomical details have been studied by the author. [*Philipp* J. *Sci.* (1937) 63, (4), 113 and 114].

Key to the species

A. Leaves rigid ; calyx tube campanulate ; segments subulate, fleshy

B. Lobes of leaf rounded, sinuses between lobes hardly any, peduncle terete . . 1. *C. maxima*

BB. Lobes of leaf acute, sinuses between the lobes usually deep, peduncles obtusely 5-gonal . . . . 2. *C. Pepo*

AA. Leaves soft, calyx tube very short or none, segments foliaceous at the tips . 3. *C. moschata*

1. ***Cucurbita maxima*** Dachesne. in Lam. Dict. ii. 151 ; F.B.I. ii 622 ; Cogn. in DC. Mon. Phan. iii, 544 ; Field & Gard. Crop 55 ; Watt., Dict. Econ. Products i, 638. Naud. in Ann. Sc. Nat. Sen. 4, vi, 17.

Melon-pumpkin, squash gourd, red gourd. Vern. Beng. *Kumra ;* Hind. *Mitha-kaddu, kadu ;* Bomb. *Lal-bhopali lal-dudiya ;* Kangra. *Tookm kadu ;* N. W. Him. *Garuwa ;* Tam. *Pushini ;* Tel. *Gummadi ;* Mal. *Mottanga.*

Annual ; leaves with 5 shallow lobes or subentire, 4-6 in. in diam., hispidulous and also with much soft hair ; innumerable club shaped, minute glands on the lower surface of the leaf ; stems between the lobes narrow, denticulate ; hairs of the petiole equal not pungent ; petiole often nearly as long as the blade. Male peduncle 4 in. female $1\frac{1}{2}$ in. ; calyx segments lanceolate linear ; corolla 3-4 in.; fruiting peduncle stout striated not grooved. Flowers March to June.

Habitat

Cultivated throughout India and distributed through cultivation in all tropical and temperate zones of the world.

Medicinal and other uses

The seeds are used medicinally ; the oil as a nervine tonic. The pulp of the fruit is often used as a poultice. " The fruit cut into small circular chips is a good application to relieve the burning of hands and feet in fevers." (Asst. Surgeon Bhagwan Dass, 2nd. Surgeon, Rawalpindi, Punjab). " The pulp is used as a poultice to boils and curbuncles " (T. Ruthnam Moodeliar, Chingleput, Madras). " Hospital Assistant Gopal Chandra Gangooli says that he has used the boiled pulp of the fruit as a poultice, for unhealthy ulcers with good effects " (Asstt. Surgeon Ananda Chandra Mukherjee, Noakhali). " The part of the fruit stalk in immediate contact with the ripe gourd, is removed and dried, and when made into paste by rubbing in water, is considered a specific for bites of venomous insects of all kinds, chiefly for that of the centipede " (Honorary Surgeon P. Kinsley, Chicacole, Ganjan). " The doses recommended is an ounce and a half beaten up with sugar. I have tried pumpkin seeds such as are sold in Calcutta as a vermifuge on one patient, a European male adult. He took 4 to 5 ounces without any effect whatever except distention of the abdomen." (Medical Examiner June, 1878 ex D.E.P).

This plant produces the largest known Cucurbitaceous fruit, in some case weighing as much as 240 lb., and measuring nearly 8 ft. in circumference. The fruit is wholesome and when young is used as a vegetable. It is sweetish and yellow, when mature it will keep for many months if hung up in an airy place. It is largely used by Indians of all classes in curry.

There are several varieties of this plant common in the gardens as a rainy season vegetable. The commonest one is a large globular gourd and of a brown colour. The young fruit resembles the vegetable marrow in flavour but the full-grown fruit is very good. The seeds should be sown from April to June. The plant requires a very rich soil and the general treatment is the same as *Lagenaria vulgaris.*

Occurrence

Assam	Gauhati, March 1902, Coll. A. C. Chatterjee; Mangaldai, March 1902, Coll. A. C. Chatterjee; Dhubri, June 1902, Coll. A. C. Chatterjee.
Laccadives	Minikoy, Coll. H.M.I.M. Investigator, 1891, Dec. 5; Western Pettah 1876.
Bengal	Cultivated Royal Botanic Garden, Calcutta, June 1903.
Burma	Opposite Minbu, 8 March 1903, Coll. Aubert & Gage.
Pen. India	Chepauk Garden, Madras, 12th November 1901.

The name squash is given in America to numerous varieties of gourd which bear variously shaped fruits which go by the semipopular name *C. Melopepo*. In reality squashes come under the species *C. maxima*, several varieties of which are cultivated in America.

In the Darjeeling and Khasi Hills *Schium edule* S.W., an extensive climber, is a common cultivated vegetable. This is a monoecious plant with perennial root stock and yellow flowers. The fruits which are pyriform with distant soft spines, grow up to 4·5 inches in length. It is locally called *quash* the name probably derived from English squash. At certain period of the season it is the most plentiful vegetable of the localities.

2. ***Cucurbita Pepo*** Linn. Sp. Pl. 1010, Roxb. Fl. Ind. iii, 718; W. & A. Prodr. 351, F.B.I. ii 612; Cogn. in DC. Mon. Phan. iii 545; DC. L' Orig. Pl. cult. 202; Field & Gard. crops ii, 58; Wall. E.D.; Naud. in Ann. Sc. Nat. Ser. 4, vi, 29; Wall. Cat. 6722.

The pumpkin, vegetable marrow; Vern.: Beng. and Hind. *Kumra, konda, kumara, kadmiah;* Bomb. *Keala;* Mar. *Kohala;* Kan. *Kumbala;* N.W.F.P. *Bhunga, petha;* Tel. *Potti gumuadi.*

It is difficult to separate the vernacular names which belong to this plant with *Benincasa hispida.*

Annual. Leaves 5-lobed sinus between the lobes broad, segments 5 pointed, 4-6 in., diam., with much soft hair, hispidulous on the leaves beneath denticulate; petiole as long as the blade, the hairs on the lower surface hardened into prickles. Male peduncle 4 in. or more, female 1½ in., calyx segments 5 linear lanceolate. Corolla 3-4 in. narrow towards the base, lobes erect; fruiting peduncle woody, grooved, and marked with ridges. Flower March to June.

Habitat

Cultivated throughout India. Distributed through cultivation in all warm and temperate parts of the world.

Roxburgh included this plant (the pumpkin) as well as *Benincasa cerifera* Savi (The white melon) under one species. Aitkinson, Drury, Dutt, Moodeen Sheriff, and other writers have fallen into the same mistake. The two plants may be readily distinguished by observing the stamens: in Benincasa they are inserted near the mouth of the tube, anthers are united; in Cucurbita, the stamens are inserted below the mouth and the anthers are more or less united. The fruits of Benincasa are cylindrical, 1—1½ ft. covered with a waxy bloom. Anatomical evidence of the number and nature of arrangements of vascular bundles in *Cucurbita pepo* and *Benincasa cerifera* at once separates the two species. There are four vascular bundles arranged in a straight line in *B. cerifera* but in *C. pepo* seven bundles are arranged in the form of a ring in the midribs of the leaves (Chakravarty loc. cit.).

Medicinal and other uses

The seeds are supposed to possess anthelmintic properties. Atkinson, says in the Himalayan Districts, the leaves of this plant, as also of C. maxima, are used as external application for burns. "The seeds are anthelmintic and used in cases for round worms, though uncertain in action (Civil Surgeon F. H. Thomson, Monghyr). "Grubler has isolated from pumpkin seed a crystallisable variety of albumen. Hemp and castor oil seeds also contain a similar crystalline substance" (Warden, Calcutta).

The fruit is eaten in carry, cut up into small pieces and boiled with salt or fried in oil. The young tops of the tender shoots are also sometimes fried in oil or boiled in water. There are two varieties of this plant growing and used in the same way, but differing slightly, one called the *boga kumra* and the other *ranga kumra.*

Occurrence

Bengal	Goghat, Hooghly Dist., March 11, 1902, Coll. J. D. Naskar
U.P.	Saharanpur, 1st May 1903, Coll. Mr. Gollan
Assam	Lakhimpur, Dhubri, June 1902, Coll. A. C. Chatterjee
Punjab	Lahore (cultivated)

3. ***Cucurbita moschata*** Duchesne, ex Poir. in Dict. Sc. Nat. xi (1818) 234; F.B.I. ii, 622; Cogn. in DC. Mon. Phan. iii, 546; DC. L' Orig. Pl. cult. 204; Fields & Gard. crops ii, 58, tt. LVIII-LXI; Watt E.D.; *C. Melopepo* Lour Roxb. Fl. Ind. iii, 719; *C. maxima* Wall.; W. & A. Prodr. 351; Wight Ic. 507; Kurz. in Journ. As. Soc. 1877, pt. ii 104; *C. Camolenga* Wall. Cat. 6718; Rheede Hort. Mal. viii. t. 2.

The musk Melon; Cushaw, Crooked-necked squash Vern. N.W.P. *Sitaphal, saphari kumra, kumra, kaddu, mitha-kaddu*; Bomb. *Kali-dudhi.*

Leaves cordate angular lobed, dentate, rugose harsely and densely pubescent on the underside; leaf surface often marbeled with white blötches; petiole hispid but not prickly, hairs of the petiole equal, not pungent. Fruiting peduncles angular and furrowed. Corolla campanulate broad at the base; segments of the calyx often dilated at the apex (spathulate) into an obovate-oblong toothed foliaceous limb; divisions of the corolla recurved. Fruit large oval spherical, glabrous, torulose. Colour of the fruit pulp yellow or orange.

Flowers March to October.

There are two primary forms one with the fruit smooth but mottled brown and yellow (*c. moschata* proper) and the other with fruit torulose or fluted with 15 to 30 ridges (*C. Melopopo* Roxb.)

Habitat

Very extensively cultivated throughout India. Distributed widely through cultivation in tropical and subtropical regions.

As stated above there are two forms of the fruit one smooth and somewhat oblong in shape the other fluted and flattened spheroidal. It seems probable that the latter (the melopepo of Roxburgh) is by many Indian writers described as *C. maxima.* The long account given by Firminger (Man. Gar. for India, 128) under the heading "*C. Melopepo,* squash" has reference to imported seed of Squash, gourd or vegetable-marrow and not to the Indian cultivated fruit, *C. moschata.* He says, in Bengal it should be sown in October but in the North-West Province not before the end of February, as the plants will not live in the cold season, of these provinces. Duthie and Fuller (in *Field and Garden crops,* Part ii, lvii to lx) give an account of *C. moschata,* but do not mention any fact regarding method of cultivation, season etc. They state that only the *Cucurbita* appears to occur in the North-West Provinces. Their plates seem to represent the form Roxburgh called *M. Melopepo* and not his *C. moschata* proper.

The yellow flesh of this fruit is extensively cooked and eaten as a vegetable throughout India.

Occurrence

Assam	Lakhimpur, Sadiya Bazar, 22nd August 1909, Coll. R. K. Das; Rotung 1,000 ft. 28-12-1911, Coll. I. H. Burkill
Bengal	cultivated, S. Kurz
Nicobar Isls	Katchall, February 1875, Coll. S. Kurz
Burma	Tonkyeghat, F. pagodas, cult; Pegu, Oct. 1904, Coll. S. Kurz
Andaman	South Point, S. Andaman, Coll. S. Kurz
Bengal	Goghat, 11th March 1902, Coll. J. D. Naskar; Noagaon near Ranir Bazar 600-900 ft., Hill Tipperah, June 1916 Coll. P. M. Debbarman
Central India	Indore 20-10-18, Coll. P. Mukherjee

14. Thladiantha

Thladiantha, Bunge Enum. in pl. Chin. Bor. p. 29 et in Mem. Sav. Etr. St-Petersb. 2, 1835, p. 103; Meisn. Gen. p. 126 (91); Endl. Gen. p. 940; Walp. Rep. v. 2, p. 205, v. 5, p. 763; Roem, Syn., fasc. 2, p. 19; Naud. in Ann. sc. nat. ser. 4, v. 12, p. 150 et set. 5, v. 6, p. 11; Benth. et Hook. Gen. 1, p. 825; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 630.

Climbing herbs; tendrils simple rarely 2-fid. Leaves petioled, entire or tripartite, deeply cordate, denticulate, softly pubescent or nearly glabrous. Flowers dioecious, yellow, large or small. Male

peduncles in the fully developed plant paired, one 1-flowered ebracteate caducous, the other racemed; flowers with or without bracts; female peduncle elongate, 1-flowered, ebracteate. *Male*: calyx tube shortly campanulate, the bottom stout by a horizontal scale; segments 5, lanceolate; corolla campanulate, 5-partite, segments revolute about half way down; filaments 5, inserted near the mouth of the calyx tube; anther 1-celled, narrow oblong, straight. *Female:* calyx and corolla as in the male; ovary oblong, style deeply 3-fid with 3-reniform stigmas; ovules many horizontal; placentas 3 vertical. Fruit ellipsoid, obtuse, indehiscent, green cylindric with vertical ribs. Seeds many, horizontal, small obovoid, compressed, smooth. Distrib.—Species 2, Bengal, Malaya, China.

The generic character is here widened to include the Khasia species. As in most cucurbits with paired male peduncles, either the simple or the racemed one is often wanting and the two do not flower together; the simple peduncle generally falls off by the time the racemed one is in blossom. The corolla is slightly oblique; in *T. calcarata* besides the normal large male flowers much smaller imperfect ones are often found.

Key to the species

A. Male recemens with prominent bract	1. *T. calcarata*
AA. Male racemes without bracts	2. *T. Hookeri.*

1. ***Thladiantha calcarata*** C.B. Clarke in Journ. Linn. Soc. xv (1876) 126; *T. dubia* Bunge Enum. Pl. Chin. Bor. 29; Naud. in Ann. Sc. nat. Ser. 4, xii, 105, t. 10; Bot. Mag. t. 5409; Kurz. in Journ. As. Soc. 1877, pt. ii. 102; *Momordica calcarata* Wall. Cat. 6740; *Gymnopetalum Horsfieldii* and *peperifolium* Miq. Fl. Ind. Bat. i. pt. i. 680.

A large climber. Leaves deeply cordate ovate, acute, undivided 4 by 2½ in., denticulate not at all angular, usually villous beneath sometimes nearly glabrous; petiole 1½ in. Tendrils simple in all the wild examples, but Naudin reports of bifid tendrils in cultivated species. Male racemes 2-3 in., golden yellow, petals ¾ in. bracts prominent serrate or incise-serrate; calyx-teeth very narrow; filaments minutely hairy. Female peduncle 2-3 in. more or less hairy; young ovary densely wooly. Fruit 1½ by ¾ in., glabrous, obtuse at both ends. Seeds scarcely ¼ in. Flowers March to June.

Habitat

Plains of East Bengal common, ascending to 8,000 ft., in the hills. The female plant is rare and has never been collected in plains. Pegu, Kurz; Distrib. Malaya and China.

Occurrence

Wall. Cat.	Sylhet, 6740 A; Royal Botanic Garden Cal., 6740 B; Goalpara, 14th May 1808 6740 C.
Bengal	E. Bengal, Pubna and neighbourhood, April 1867, Coll. S. Kurz; Chittagong hill tracts, River bank Waga Sera hill 35 miles from Chittagong, September 1885, Coll. Badul Khan Dr. King's collector; Chittagong hill tract, Coll. J. Wood.
Bihar	Dalsing Sarai Darbhanga, Aug. 1900, Dr. Prain's collector; Silsaku, north side of Brahmaputra.
Assam	Gauhati, April 1902, Coll. A. C. Chatterjee; Managaldai jungle March 1902 Coll. A. C. Chatterjee, Ligri Pukri Sibsagar, March 1895, Coll. Reporter of Economic Products to the Govt. of India; Khasi Hills 4-5000 ft., June 1867, Coll. S. Kurz; lower Khasi hills April 1876, Coll. S. Kurz; Mount Khasia 0-4,000 ft., Coll. T. D.H.&T.T.; E. Bengal; Poishing 4,000 ft., Manipur, April 25th 1882; Talap-Lakhimpur 24-3-1894, Coll. G.A. Gammie Kohima 3,600 ft., Naga Hills May 1886, Coll. Dr. D. Prain; Konoma 5,000 ft., April 1896, Coll. Dr. King's collector.
Burma	Modar plains, Tenasserim, 25-4-77, Coll. Geo. Gallatly; Keng Tung 2,000 ft., May 1909, S. Shan States, Coll. Mac Gregor Mogok 5,000 ft., Ruby Mines Division, May 1910, Coll. A. Rodger; Bhamo, July 1892, Coll. Abdul Huk; between Ridge camp and Lungsia 2-3,000 ft., April 20, 1899, Coll. A. T. Gage; Shan States 1890, Coll. Abdul Huk; Pegu Yomah and W. Stopes 1-3-71, Coll. S. Kurz.
Sikkim	Toong 5,000 ft., 6-7-09, Coll. Smith & Cave; Ryang valley 2,500 ft., 8th May 1874, Coll. G. King, Darjeeling 5,000 ft. Oct. 1881, Coll. J. S. Gamble; Sikkim, Coll. G. King; Sikkim 4-7,000 ft., Coll. J. D. H; Rungno valley Coll. S. Kurz; Rishap, 13th February 1867, Coll. T. Anderson; Popore, 2,400-4,000 ft., 8-7-1862, T. Anderson.

2. ***Thladiantha Hookeri*** Clarke in Hook. F. Fl. Brit. Ind. ii. 631.

A large climber; tendrils simple. Leaves polymorphous deeply cordate ovate, acute, entire resembling altogether those of *T. calcarata* but generally less hairy and thinner, or tripartite with lanceolate segments, 4 by 1¾ in., the two lateral lobes very cordate and auricles on the outer base; petiole 2 in. The female flower in Griffith's example resembles that of *T. calcarata* but is smaller though the petals are slightly more than ½ in.; peduncle about 1 in. Male racemes 1½ in., slender; flowers pedicelled scattered, yellow petals scarcely ¼ in.; these small flowers probably correspond to the small imperfect males of *T. Hookeri* which are as yet unknown. Fruit (and seeds) altogether like those of *T. calcarata* but rather smaller, 1¼ in. The ebracteate male racemes of this with pedicles ½ in. is exceedingly unlike that of *T. calcarata*, but in all others points they appear congeneric, and the habit is the same.

Flowers May to December.

Habitat

Assam, Griffith (Kew Distrib. No. 767, 2553); Khasia alt. 4-6,000 ft.; Myrung & Nanklow H.f.&T.

Occurrence

Assam	Haflong 2,500 ft., N. Cachar, 26th Aug., Coll. W. G. Craib; Jowai, December 1893, Coll. Dr. King's collector; Cachar and Manipur frontiers 4,000 ft. May 1882, Coll. G. Watt; Mapoong 3,000 ft. 27th May 1882, Manipur Coll. G. Watt; Kala Naga Hills, May 1882, Manipur, Coll. G. Watt; Neechoogard 1,000 ft., Naga Hills 18th Oct. 1885, Coll. C. B. Clarke; Khasia 4-6,000 ft., Coll. J.D.H.&T.T.; Road to Kohima 4,500 12th May 1895, Coll. Reporter on Economic Products to the Government of India; Lushai Hills, 30th July 1924, Coll. Mrs. Parry
Burma	Kachin Hills, Upper Burma, 1897, Coll. Shaik Mokim

15. Edgaria

Edgaria, C.B. Clarke in Journ. Linn. Soc. 15, 1876, p. 113 et in Hook. f. Fl. Brit. Ind. ii, 631.

A large scandent herb; tendrils 2-fid. Leaves petioled, entire, ovate, acute deeply cordate, more or less pubescent. Flowers large dioecious, yellow. Male peduncles paired, one 1-flowered caducous, the other racemed; bracts 0, or inconspicuous; female peduncle elongate, 1-flowered. *Male:* calyx tube, elongate, funnel shaped, teeth 5, subulate; corolla deeply 5-partite, with obovate acute segments; stamens 3, included in the calyx tube, two 2-celled; cells straight, linear oblong, connective not appendaged. *Female:* calyx and corolla as in the male: ovary narrow-obovoid, 3-celled; style long, stigma 3, oblong, 2-fid; ovules 1-3 in each cell, pendulous, compressed, subquadrate, large, corrugate or somewhat 3-lobed at the lower end and faces when dry.

Edgaria darjeelingensis C.B. Clarke in Journ. Linn. Soc. xv (1876) 133; *Gymnopetalum* sp. 5, Hook. Ind. Ori., H.f.&T.

Leaves 4 by 3½ in., serrate and denticulate; petiole 3. Male raceme 6 in., female 3-4 in. Calyx tube ⅜ in. Petals ¾ in., widely patent. Fruit 3 by 1¼ in. Somewhat pilose, with 2 wavy vertical ribs on each face.

Flowers May to October.

Habitat

Garwhal, Falconer; Sikkim 5,000 ft., very common, J.D.H. & C.B. Clarke.

Occurrence

N.W. Himalaya . . .	Sept, 1882. Simla 17500, Sept. 9877,Coll. Gamble,
Eastern Himalaya . . .	Mission Compound, 4,000 ft., Kalimpong Dist., Coll. A.J.C. Kingdom ; Phadon, chee 8,000 ft., 20-8-1910, Coll. W. W. Smith ; Senchal 8,500 ft., 28-8-10. Coll. W. W. Smith ; Rungno valley, 6,000 ft., May 1862, Coll. J. Anderson- North side of Senchal, 7,200 ft., August 1862, Coll. T. Anderson ; Coll. G, King ; 6,000 ft., 1881, Coll. G. King ; 12-10-68, Coll. S. Kurz ; Ghoom 3rd Mile, 13-8-13 ; Sikkim 5-7,000 ft., Coll. J.D.H. ; Mungpoo 4,000 ft., 1st Oct. 1884, Coll. C. B. Clarke ; Gassing to Ratong River 3-10-1862, Coll. T. Anderson ; Senchal 8,000 ft., Darjeeling, September 1880, Coll. G. S. Gamble ; Rungbee, Darjeeling, 13th Aug. 1869, Coll. C. B. Clarke ; Darjeeling 6,500 ft., 16th Oct. 1776, Coll. C. B. Clarke ; Goompahar 8,000 ft., Darjeeling 12th Sept. 1875 ; Darjeeling 7,000 ft., 9-9-75, Coll. G. S. Gamble ; Kurseong and about, Sept. 1943, Coll. H. L. Chakravarti.

16. Bryonopsis

Bryonopsis, Arn. in Hook. Journ. of Bot. 3, p. 274 ; Wight in Ann. and Mag. of Nat. Hist. 8, p. 267 ; Meisn. Gen. comm. p. 356 ; Endl. Gen. suppl. 2, p. 76 ; Roem Syn. fasc. 2, p. 10, 32 ; Miq. Fl. Ind. Bat. 1, part 1, p. 656 ; Naud. in Ann. sc. nat. ser. 4, v. 18, p. 193 ; Hook. f. in Oliv. Fl. trop. Afr. 2, p. 556.—Bryoniae sect. Diplocyclos Endl. Prodr. fl. Norf. p. 68.—B. sect. *Bryonopsis* Hook. f. in Benth. et Hook. Gen. 1, p. 829 (non Bl.).

Annual scaberulous scandent herbs. Tendrils 2-fid. Leaves deeply palmately 5-lobed. Flowers monoecious, the male and the female fascicled, often in the same axils. *Male flowers :* calyx tube broadly campanulate ; lobes 5, subulate. Corolla campanulate, 5-partite ; segments ovate. Stamens 3, free, inserted on the calyx tube, filaments short ; anthers cohering, one 1-celled, the others 2-celled ; cells flexuose round the broad connective, which is not produced at the apex. Pollen muriculate. Rudimentary ovary o. *Female flowers :* calyx and corolla as in the male. Staminodes 3, small. Ovary globose or ovoid, 3-placentiferous ; ovules numerous, horizontal ; style slender ; stigmas 3, papillose, deeply 2-boled. Fruit baccate, spherical or ovoid conical, pulpy, many seeded. Seeds subpyriform, very turgid, surrounded by a very thick grooved crenulate ring, on each side of which the tumid faces of the seed project.

Distrib. S. Asia, Indian and Pacific Islands, Australia ; species 2 of which *B. laciniosa* Naud. is confined to India.

Bryonopsis laciniosa Naud. l.c. Ser. VI (1886) 30. Hook. f. in Oliv. Fl. Trop. Afr. v.2, p. 556 ; Cogniaux in DC. Monogr. phan v.3, p. 477. *Bryonia laciniosa* Linn., Sp. Pl. (1753) p. 1013 ; C.B. Clarke in Hook. f. Fl. B.I. ii, p. 622 ; Garh. Cat. p. 78 ; Dalz. & Gibs. p. 101 ; Trim. Fl. ceyl. v.2, p. 254 ; Woodr. in Journ. Bomb. Nat. v. ii (1898) p. 640 ; Watt. Dict. Econ. Prod. i. p. 542 ; Roxb. Hort. Beng. 104 ; Fl. Ind. iii, 728 ; Blume Bijd. 927 ; Wall. Cat. 6699 ; W.&A. Prodr. 345 ; Miq. Fl. Ind. Bat. pt. i, 660 ; *Bryonopsis courtallensis* Arn. in Hook. Journ. Bot. iii. 274 ; *B. erythrocarpa* Naud. in Ann. Sc. Nat. Ser. 4, xviii. 194.

The Bryony ; Vern. : Hind. *Gargu-naru ;* Beng. *Mala ;* Bomb. *Kawale-che-dole ;* Mal. *Nohoe-maka ;* Tel. *Lingadouda.*

Stem much branched, slender, grooved, glabrous or scabrous. Tendrils slender, striate, glabrous, 2-fid. Leaves membranous 4-6 in., generally deeply palmately 5-lobed, sinus sometimes shallow, long and about as broad, green and scabrid above, paler and smooth or nearly so beneath, deeply cordate at the base, margins sinuate, distantly denticulate, sometimes subserrate ; petioles 1-3 in. long, striate, slender. *Male flowers* in small fascicles of 3-6 ; peduncles $\frac{1}{5}$–$\frac{3}{4}$ in. long, filiform, glabrous. Calyx glabrous $\frac{1}{10}$ in. long ; teeth subulate, less than $\frac{1}{20}$ in. long. Corolla $\frac{1}{8}$–$\frac{1}{6}$ in. long ; segments ovate-oblong, acute, pubescent. *Female flowers* solitary or few, or many ; peduncles shorter than in the males. Fruit often 2-3 together, subsessile $\frac{1}{2}$–1 in. in diam., globose, smooth bluish-green streaked with broad vertical lines. Seeds with a thickened corrugate margin, often with protuberences on the faces, $\frac{1}{5}$–$\frac{1}{4}$ in. long, yellow-brown.

Flowers August to November.

Habitat

From Himalaya to Ceylon, Pegu, Kurz. Distributed to tropical Africa, Mauritius, Malaya, Australia.

Medicinal and other uses

"The whole plant is collected when in fruit for medicinal use. It is bitter and aperient, and is considered to have tonic properties" (Dymock*). It is also used as a medicine by the Santals. The leaves are boiled and eaten as greens.

Occurrence

Calcutta Botanic Garden	Wild, 21-10-58
Malay Peninsula	Mt. Malabar 4,700 ft., Java, Oct. 19, 1861, Coll. T. Anderson M. D.; Java; Tjilaki Preanjee 4,700 ft., 4-3-1880, Coll. H.O.Forbes
Assam	E. Bengal, Herb. Griffith ; E. Sylhet
Wall. sheets	6769 C ; Goalpara, Assam 8th August 1808, 6699 ; 6699 F ; 6699 A ; H.B.C. 6699 H.
Central India	Guna, Isagarh Dist., September 1867, Coll. G. King M.B. and Coll. Dr. Barkley 1876 ; Abu Sirohi, Rajputana ; Sagor, Vicary
Bihar	Hazaribagh 1,500 ft., Chota Nagpur, Nov. 1886, Coll. G. Gamble
Himalayan N. W.	Lambatach 7-8,000 ft., Tehri Garhwal U. P. 2-6-94, Coll. J. F. Duthie ; Northern India ; Mussooree Range 1869, Coll. G. King ; near Mussooree Dehra Dun Dist., U.P. 1869 Coll. G. King
Burma	Keng Tung 4,000 ft., S. Shan States, December 1909, Coll. Capt. R. W. Mac Gregor, M. S. ; Taunggyi, Yawnghwe State Upper Burma 1894, Coll. Abdul Khalil, Mooyet 5,000 ft., Tenaseerim 27-1-1887, Coll. Geo. Gallatly
Peninsular India	Poona, August 1892 ; Alagai Hills, 1,100 ft., Madura District, Madras S. India, 9-11-1911, Coll. C. E.C. Fischer ; Machur Road 5,500 ft., Madras, 1-8-12, Coll. Rev. St. Munch S. J. ; Koni, Travancore 24-8-1913, Coll. C. C. Calder & M. S. Ramaswami ; Koni, Travancore 6th September 1903, Coll. M. Rama Rao ; Quilon, Travancore 21-9-13, Coll. Rama Rao's collector, Shevaroy Hills, Salem Dist., Madras, collection Perrottet ; Gaidmalam 3,200 ft., Coimbatore Dist., 20-8-05, Coll. C. E. C. Fischer ; Mont. Nilgiri and Coorg region Coll. G. J. ; Gudalur Ghat, Nilgiri, 9th January 1903, Coll. C. A. Barber ; Culhatty 5,000 ft., Nilgiris 26th March 1870, Coll. C. B. Clarke ; Alagar Hills 1,100 ft., Madura District, 9-11-1911 Coll. C. E. C. Fischer ; Perumal Road 5,500 ft., Madras, 4-2-1913, Coll. Rev. Aug. Saulieres ; Nilgiri, August 1852, Herb. Wight ; Naterikal 4,000 ft., Tinnevelly District 13th February, 1913, Coll. D. Hooper & M. S. Ramaswami
Bengal	Agartala 800-1,000 ft., Hill Tipperah 30-9-14, Coll. P. M. Debbarman ; Agartala 600-800 ft., Hill Tipperah Sept. 1915, Coll. P. M. Debbarman ; Hoshenpore, Mymensing Nov. 1868, Coll. C. B. Clarke ; Sibpur, April 1865, Coll. S. Kurz ; Bengal. Rejioo. trop. Coll. J. D. H. & T. T. ; Beliaghata near Calcutta, April 1943, Coll. H. L. Chakravarti
Bihar	Ranchi 2,000 ft., Chota Nagpur, 13th Oct. 1873, Coll. C. B. Clarke ; Thakurganj, Purnea District, 27th January 1911, Coll. J. H. Barkill ; Ganja Mahal February 1893, Coll. D. Prain ; Raikote 2,000 ft., Lohardaga, Chota Nagpur, 30th Oct. 1882, Coll. C. B. Clarke
Upper Gangetic Plain	Banda, U.P., Hedges uplands, 16-12-1900 Coll. Mrs. A. S. Bell, Vern.—Pachgurria, seshrgi
N.W. Himalaya	Chamba Punjab, August 1880, Coll. Comm. Robert Ellis, Afghanistan. Badghis, April 29th, 1885, Coll. J. E. T. Aitchison
Malay Peninsula	W. Java, Coll. S. Kurz

17. Melothria

Melothria Linn. Hort. Cliff. p. 490 (1737), Gen. ed. 2, p. 20, ed. 6, p. 24, Spec. ed. 1, p. 35, ed. 2, p. 49 ; Juss. Gen. p. 395 ; Schreb. Gen. 1, p. 32 ; Lour. Fl. Cochinch. 1, p. 35 ; Willd. Spec. 1, p. 189 ; Nutt. Gen. 2, p. 228 ; Ser. in DC. Prodr. 3, p. 313 ; Spach. Veg. phan. 6, p. 225 ; Meisn. Gen. p. 127 (91) ; Endl. Gen. p. 936 ; Torr. et Gr. Fl. N. Amer. 1, p. 540 ; Roem. Syn. fasc. 2, p. 9, 27 ; Benth.

*Dymock, W. (1885). *Materia Medica West. Ind.* 346.

in Hook. Niger Fl. p. 367; Naud. in Ann. sc. nat. ser. 4, v. 12, p. 148; v. 16, p. 168, v. 18, p. 195; Benth. Fl. Austral. 3, p. 320; Benth. et Hook. Gen. 1, p. 830; Hook. f. in Oliv. Fl. trap. Afr. 2, p. 562; Cogn. in Mart. Fl. Bras. fasc. 78, p. 25; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 625. *Solena*, Lour. Fl. Coch. p. 514 (1790), ed. Willd. p. 629; Ser. in DC. Prodr. 3, p. 306; Roem. 1.c.p.11, 33; *Zehneria*, Endl. Prodr. fl. Nor. p. 69 (1833).

Slender scandent or prostrate herbs, annual or with a perennial root, monoecious or very rarely dioecious. Tendrils simple or rarely 2-fid. Leaves usually membranous, entire or more or less lobed. Flowers small, yellow or white. *Male flowers* racemose or corymbose, less commonly fascicled or solitary. Calyx campanulate, 5-toothed. Corolla deeply 5-partite; segments entire. Stamens 3, inserted on the tube (rarely at the base) of the calyx; filaments free; anthers free or rarely slightly cohering, one 1-celled, the cells straight rarely curved, the connective sometimes produced. Rudimentary ovary, globose or annular, rarely 3-lobed. *Female flowers* solitary, fascicled or corymbose. Calyx and corolla as in the male. Staminodes 3 or 0. Ovary ovoid, globose or fusiform, 3-placentiferous, constricted beneath the flower; ovules usually numerous horizontal; style short, surrounded at the base by an annular disk; stigma 3 linear, rarely 2 or stigma 3-lobed. Fruit small, baccate, globose, ovoid or fusiform, usually many seeded. Seeds ovoid or ellipsoid, compressed, usually margined. Smooth or rarely scorbiculate. Distrib. Warmer regions of the globe; species 54 of which 11 occurring in India.

KEY TO THE SPECIES

A. Flowers monoecious
  B. Male flowers fascicled
    C. Seeds smooth on their faces; leaves hispid beneath with long soft hair; cordate at the base . . . . 1. *M. leiosperma*
    CC. Seeds scorbiculate; leaves very scabrous rough, hispid beneath, cordate at the base . . . . 2. *M. maderaspatana*
    CCC. Seeds scorbiculate; leaves more or less amplexicaule . . . 3. *M. amplexicaulis*
  BB. Male flowers subumbellate at the apex of the peduncle
    C. Fruit globose . . . . 4. *M. perpusilla*
    CC. Fruit ellipsoid . . . . 5. *M. mucronata*
  BBB. Flowers frequently monoecious on the same axis sometimes apparently dioecious. Male flowers with long pedicles, clustered in the axils or clustered on long racemes resembling branches with outleaves . . . . .
    C. Fruit globose, subquadrate, obtuse
      D. Male pedicles clustered in the axils . . . . . 6. *M. indica*
      DD. Male pedicles in distant clusters on long racemes . 7. *M. odorata*
    C.C Fruit fusiform, subtrigonus
      D. Male pedicles clustered in the axils . . . . . 8. *M. zeylanica*
      DD. Male peduncle racemed . . . . 9. *M. Wallichii*
      DDD. Male inflorescence elongate . . . . . . 10. *M. bicirrhosa*
AA. Flowers dioecious . . . . 11. *M. heterophylla*

1. ***Melothria leiosperma*** (W.&A.) Cogniaux, in DC. Monogr. Phan. v. 3 (1881) p. 622; Jackson, in Index Kew. v. 3, p. 203; *Mukia leiosperma* Wight in Ann. Mag. Nat. Hist. v. 8 (1842) p. 268; C. B. Clarke, in Hook. f. Fl. B.I. v.2, p. 623; Trin. Fl. Ceyl. v. 2, p. 255; *Bryonia leiosperma* W. & A. Prodr. 345; *B. mysorensis* Miq. in Herb. Hohenach.

Monoecious; stems hispid, furrowed slightly branched; young parts densely and softly villous hairy. Tendrils simple. Leaves 2-3½ by 1¾-3 in., bright green above, paler beneath, broadly ovate in outline, acute, cordate at the base, scabrid and coarsely hairy above, softly villous beneath, usually 5-angled or slightly 3-5-lobed, strongly dentate; petioles ½-2 in. long, densely hairy. Flowers axillary. Male flowers fascicled; peduncles very short. Calyx densely hairy; tube ⅛ in. long, campanulate; teeth linear subulate, ⅓-⅙ in. long. Corolla pubescent outside; segments ovate oblong ⅛ in. long. Anthers subsessile, oblong, the connective short, apiculate. Female flowers: peduncles usually solitary ¾-2 in. long, thickened in fruit, densely clothed with long hairs. Ovary densely hairy. Fruit ½ in. in diam., globose, glabrous or slightly hairy. Seeds ellipsoid ⅛ by ⅛ by $\frac{1}{12}$ in., turgid, conspicuously margined, smooth on the faces.

Flowers May to December.

Habitat

Deccan Peninsula; Pulney Mts., Wight; Nilgiris G. Thomson, Hohenacker. Ceylon; alt. 4,000-5,000 ft., Thwaites.

Occurrence

Peninsular India & Ceylon .	Poombari, Pulneys 5th June 1898, Coll. A. G. Bourne; Pariakanal, 5,000 ft., Travancore December 1910 Coll. A. Meebold; Kavunji 6,300 ft., Upper Plains, 21-9-1911, Coll. C. E. C. Fischer; Shembaganur 6,000 ft., 8-7-12, Coll. Rev. St. Munch S.J.; Perumal Road 5,500 ft., 4-12-1913, Coll. Rev. Ang. Saulieres; Coonoor 5,000 ft., May 1885, Coll. J. S. Gamble.

2. **Melothria maderaspatana** (L.) Cogniaux. in DC. Monor. Phan. v. 3, (1881) p. 623; Jackson in Index Kew, v. 3, p. 203; *Mukia scabrella*, Arn. in Hook. Journ. Botany, v. 3 (1841) p. 276; C.B. Clarke in Hook. f. Fl. B.I. v. 2, p. 623; Dalz. and Gibs. Bomb. Fl. p. 100; Ait. Pb. & Sind. Pl. p. 64; Trim. Fl. Ceyl. v.2, p. 254; Woodr. in Journ. Bomb. Bat. v. 11 (1898) p. 640; Watt. Dict. Econ. Prod. v. 5, p. 287. *Bryonia maderaspatana* and *althaeoides*, DC. l. c. 306; *Karavia javanica* Miq. l. c. 661; *Trichosanthes dioica* Wall. Cat. 6692 C.

Annual, monoecious; stems scandent or prostrate slender, much branched, angular, very hispid, young part densely covered with white hair. Tendrils simple striate, sparingly hirsute. Leaves variable in size, 1-5 by 1-4 in., deltoid-ovate, entire, 5-angled, or 3-5 lobed, very scabrid above, scabrid or shortly hispid beneath, acute at the apex, cordate at the base with a wide sinus, the lobes often overlapping, the margins dentate or subserrate; petioled $\frac{1}{4}$-1 in. long, hairy. *Male flowers* in small fascicled on very short peduncles. Calyx hairy; tube $\frac{1}{12}$ in. long, narrowly campanulate; teeth about $\frac{1}{20}$ in. long, subulate. Corolla pubescent; segments ovate-oblong, rounded at the apex, $\frac{1}{12}$ in. long. *Female flowers* almost sessile. Fruit the size of pea, smooth or slightly echinulate, at first green and variegated with yellow, finally woody red. Seed ellipsoid, compressed, not or scarcely margined, scorbiculate on both faces.

Flowers August to October.

Habitat

Throughout India common; ascending the hills as far as the subtropical region. Distributed: Africa, Malaya and Australia.

Occurrence

Java	Batavia Oct. 1879, Coll. G. King; Java. 1859, Coll. T. Horsfield M.D.
Wall. Cat.	6708 C or G; Goalpara 25th Sept. 1868, 6708 E; Sukanagar 6th August 1880, 6708 E; Prome hills 15th Sept. 6708 F; H.B.C. 6708 H; 6708 L; Rangoon 1826; 6703; Pegu 11-1-75, Coll. S. Kurz; Rangoon, Coll. R. Scott; Pegu Yomah Coll. S. Kurz
Peninsular India & Ceylon .	Naduvettumuri 26-8-1913, Travancore State, Coll. C. C. Calder & M. S. Ramaswami; Shevaroy hills, S. India collection Perrottet; Nilgiri hills, Coll. Mr. Schmidt.; Sigur ghat 5,000 ft., Nilgiri Dist., June 1884, Coll. G.S. Gamble; Carwar, N. Canara, August 1883, Coll. W. A. Talbot; Malabar Concon Coll. Stocks; Sind. Coll. Stocks; Rajkot; Belgaum, September Coll. Ritchie; Ceylon very abundant upto an elevation of 3,000 ft.; Kavalay Cochin 2,000 ft., Nov. 1910, Coll. A. Meebold; Gudalur 5,000 ft., Nilgiris, Oct. 1910, Coll. A. Meebold; Cherretggyam 1,500 ft., Cochin Nov., 1910, Coll. A. Meebold; Guijagudem, Godavari District, 13th August 1914, Coll. M. S. Ramaswami M.A.
Burma	Mree Hill, Maymyo 3,600 ft., Sept. 12th, 1915, Coll. A. Rodger I.F.S.; Maymyo plateau alt. 3,500 ft., 6th October 1908, Coll. J. H. Lace; Keng Tung 400 S. Shan, December 1909, Coll. Capt. R. W. McGregor I.M.S.; Minbu, Sept. 1902, Coll. Shaik Mokim; Upper Burma 23rd June 1890, Coll. Abdul Huk; Tyankse, Upper Burma, 10th March, Coll. Dr. King's collector; Tagunyi, Southern Shan States, Upper Burma, 1893, Coll. Abdul Khalil

Bengal	Hazarikhil, Chittagong, 11-10-05, Coll. D. Hooper ; Siliguri ; Sibpur Sept. 1864, Coll. S. Kurz ; Anand, Kaira Dist. 2nd Nov. 1902, Coll. Reporter Econ. Product. Govt. of India ; Agartala 600-800 ft., August 1915, Coll. P. M. Debbarman
E. Himalaya	Sikkim Himalaya, 2,000 ft., 3-7-1876, Coll. G. King
Assam	Goalpara, Chairang Duars plains, December 1890, Coll. Dr. King's collector ; Mont. Khasia 0-4,000 ft., Coll. J. D. H. & T.T. ; Shillong, November 1890, Coll. Robertson
N. W. Himalaya	Dwarahat 4,500 Almora Dist., 7th Oct. 1912, Coll. D. Hooper ; Kobo, Abor Expedition 15-12-1911, Coll. I. H. Burkill ; Baligan near Naga Hills, October 1898, Coll. Dr. King's collector
Bihar	Chota Nagpur, Coll. Dr. J. J. Wood ; Pareshnath Nov. 1891, Coll. D. Prain ; Hundrugagh, Chota Nagpur, Sept. 1896, Coll. D. Prain ; Muzaffarpur, February 27, 1896, Coll. D. Prain
Central India	Khandwa 3-12-88, Coll. J. F. Duthie
Gangetic Plain	Tropical region 1,000 ft., Coll. T.T. ; Trunk Road 9-58, Coll. T.T. ; near Etawah near Bundelkhand 24-11-86, Coll. J.J. Duthie ; Banda N.W.P., vern. Bankakri August 1902, Coll. Mrs. A. S. Bell ; N. W. India, Hb. Royle.

3. ***Melothria amplexicaulis*** Cogn. Monogr. Phan. DC. Candolle, vol. ii, p. 621 ; *Bryonia amplexicaulis* Lam. Encycl. meth. Bot. i, p. 496 ; Ser. in DC. Prodr. 3, p. 306 ; W. & Arn. Prodr. 1, p. 346 ; Wight Ic. pl. Ind. or 2, tab. 502 ; *B. umbellata* Wall ! List. n. 6705, K-L ; *Kaviria amplexicaulis* Arn ! in Hook. Journ. of Bot. 3, p. 275 ; Roem. p. Syn. Fasc. 2, p. 46 ; Miq. Fl. Ind. Bat. 1, part 1, p. 661.

Monoecious ; stems glabrous ; tendrils simple ; leaves on very short petioles, or almost sessile, deeply cordate or segittate at the basal lobes much longer than the petiole, ovate or oblong, entire or angled, mucronate, sinuate and toothed, dotted and slightly scabrous on the upper side, glabrous or smooth on the under somewhat coriaceous. *Male flowers* in an umbell at the apex of a slender peduncle rather shorter than the leaves ; pedicles short, without bracteoles ; calyx campanulate ; *females* solitary, very short peduncled, in the same or different axils from the males ; berry (smaller than a hazel-nut) broadly ovate, prostrate, few (about 4)—seeded ; seeds oval, thick compressed, surrounded with a thick casky closely wasted and rugose zone, the sides flattish, sprinkled with little tubercles.

Habitat

Eastern India (Wight n. 1121 in herb. Brux., Berol.; DC., Deless, Francav., Mus. par. Kew., Edin., n. 1128 in herb. hort. Petrop., Kew n. 1130 in herb. Kew. ; Rottler in herb. hort. Petrop ; Jacquemont n. 701 in herb. mus par.) ; in Mysore and Carnatic (Thomson in herb. Berol. Mus. par. Vindob.) ; in Deccan & Ellora (Ralph. n. 301 in herb. Delss.) ; at Madras (Thomson in herb. Kew.).

4. ***Melothria perpusilla*** Cogniaux in DC. Monogr. Phan. v. 3 (1881), p. 607 ; Jackson in Index Kew., v. 3, p. 203 ; *Bryonia perpusilla* Blume. Bijdr. p. 926 ; *Zehneria Hookeriana*, Ann. in Hook. Journ. Bot. v. 3 (1841) p. 275 ; C.B. Clarke in Hook. f. Fl. B. I. V. 2, p. 624 ; Trun. Fl. Ceyl. v. 2, p. 256 ; *Bryonia mysorensis* Wight. Icon. t. 758 (not of Wall) ; Dalz. & Gibs. p. 101 ; *Zehneria Baueriana* Woodr. in Journ. Bomb. Nat. v. 11 (1898) p. 640 ; Kurz. in Journ. As. Soc. 1877, pt. ii. 105 ; *Zehneria exasperata* Miq. Fl. Ind. Bat. i. pt. i. 656 ; *Zehneria scabra* Harv. & Sond. Fl. cap. ii. 486 ; *Bryonia Hookeriana* W.& A. Prodr. 345 ; *B. cissiodes* Wall. Cat. 6698 ; *B. oxyphylla* Wall. Cat. 6697 (no flowers).

Monoecious, climbing ; root an oblong flattened tuber ; stems deeply striate, glabrous. Tendrils simple, striate, glabrous. Leaves broadly ovate in outline, $1\frac{3}{4}$-$3\frac{1}{2}$ in. long and as broad or sometimes broader than long, acute or shortly acuminate and mucronate at the apex, usually 5-angled, the angles at the base rounded, the margins distantly toothed, the upper side usually rough with scabrous spots, the lower side smooth and prominently veined, base subscordate or nearly truncate ; petiole $\frac{3}{4}$-1 in. long. *Male flowers* 3-4 at the apex of a peduncle $\frac{3}{4}$-$1\frac{3}{4}$ in. long capitate or in the subumbellate racemes ; pedicles short, filiform. Calyx tube $\frac{1}{20}$-$\frac{1}{6}$ in. long, campanulate, rounded at the base ; teeth very short recurved. Corolla pale yellow ; segments $\frac{3}{4}$ in. long, ovate oblong, subacute slightly hairy within the throat. Filaments hairy. *Female flowers* solitary or rarely subumbellate ;

peduncles $\frac{1}{4}$-$\frac{1}{3}$ in. long, in the same axils as the males. Ovary globose. Fruit smooth globose minutely pitted, red when ripe, $\frac{3}{8}$-$\frac{1}{2}$ in. in diam. Seeds many much flattened smooth.

Flowers August to December.

Habitat

North Bengal; common in Sikkim, Assam, Shakia and Cachar ascending to an elevation of 5,000 ft.; Deccan Peninsula and Ceylon common; apparently always in the lower hills. Distributed to Ava, Malaya, Africa.

Medicinal use

Root is taken with milk in fever and diarrhoea (J. J. Wood, Plants of Chota Nagpur, p. 106).

Occurrence

Peninsular India	Kavurji 6,300 ft., Upper plains 21-9-1911, Coll. C. E. C. Fischer; Ooty 7,000 ft. Nilgiris, Coll. C. B. Clarke October; Long valley, Nilgiri Hills 1878, Coll. G. King; Ootacamund 12th August 1878, Coll. G. King; Coonoor 7,000 ft., Nilgiris, 7th March 1870, Coll. C. B. Clarke; Nilgiri Hills, Coll. Schmidt., Sothamkadu 4,000 ft., 21-10-05, Coll. C. E. C. Fischer; Brahmagiris 4,500-5,000 ft., 6-12-1907, Coll. C. E. C. Fischer; Devicolam 6,000 ft. Travancore, Coll. A. Meebold; Bellaji Shola 5,000 ft., 27-8-05, Coll. C. E. C. Fischer; Naterikal 4,000 ft., Tinnevelly District, 13th February 1913, Coll. D. Hooper and M. S. Ramaswami
Burma	S. Shan States, Coll. Capt. R. W. Macgregor, I.M.S., Moolyet 5,000 ft., Tenasserim, 19-2-1877, Coll. Geo Gallatly
E. Himalaya	Sikkim, November, Coll. T. Thomson; Sikkim Himalaya 4,000 ft., 28-10-1872, Coll. J. S. Gamble; Rishap 3,500 ft., Darjeeling 31st Oct. 1870; Mungop 4,000 ft., Sikkim 2nd Oct. 1884, Coll. C. B. Clarke
Bengal	Barul, Chittagong Hill Tracts, 7-3-76, Coll. L. L. Lister
Assam	Theria 150 ft., Khasia 10th Oct. 1886, Coll. C. B. Clarke
Wall. Cat.	Nopolea 1821, 6698; Sylhet H. B. 6697
Peninsular India	Malabar Konkan, Coll. Stocks;
Ceylon	in Central Province at an elevation of 2,000-4,000 ft., Coll. Thwaites;
Assam	Kalek 3,600 ft., Abor Expedition 29-12-11, Coll. I. H. Burkill; Haflong 2,500 ft., N. Cachar, 17th August 1908, Coll. W. G. Craib; Mont. Khasia 0-4,000 ft., Coll. J. D. H. & T. T.; Kohima Naga Hills, Dec. 1866, Coll. Dr. D. Prain;
Burma	Inle Lake Southern Shan States, 27th February 1917, Coll. N. Annandale; Hotha, Yunnan Expedition, 20-8-1868, Coll. D. T. Anderson
E. Himalaya	Sikkim, 3-6,000 ft., Coll. J. D. H.; Sikkim 4th Nov. Coll. T. Thomson

5. ***Melothria mucronata*** (Bl.) Cogn. in DC. Monogr. Phan. iii. 608; *Zehneria Baueriana* C. B. Clarke; F. B. I. II 624; *Bryonia mysorensis* W.&A. Prodr. 345; Wt. Icon. t. 1609 (but not dioecious) Dalz. & Gibs. Bomb. Fl. 101; *Zehneria mucronata* Miq. Fl. Ind. Bat. i. pt. 656; *Bryonia mucronata* Blume. Bijid. 923 ? *Bryonia filiformis* Roxb. Fl. Ind. III. 727; *Karivia samoensis* A. Gray in Seem. Fl. Viti 103.

A rather slender climber, nearly glabrous. Leaves cordate acute simple or 3-5-lobed half way down, 2 in. diam. generally abruptly denticulate, petiole longer than the auricles $\frac{3}{4}$-3 in. or short. Flowers frequently monoecious in the same axils sometimes apparently dioecious; male peduncle usually 1-2 in. female less than $\frac{1}{4}$ in. undivided in all the Indian examples, but occasionally the female peduncle is elongate umbellate according to Wight. Fruit when dry reticulate rugose ellipsoid, seeds much compressed. Roxburghs *Bryonia filiformis* perhaps belongs to this species but the ripe fruit is said to be nearly 1 inch. It has been referred to *Melothria indica*, but the inflorescence is quite unlike, as are the yellow flowers and stamens of Roxburgh's.

Habitat

Deccan Peninsula; Nilgiris; Canara; Belgaum. Distributed to Malaya, Japan, Norfolk Island, Feejees; but the area cannot be separated from that of the previous species.

Medicinal use

Root is taken with milk in fever and for diarrhoea (J. J. Wood's Plants of Chota Nagpur, p. 106).

Occurrence

North Bengal	Common in Sikkim, Assam, Shasia, and Cachar, ascending to 5,000 ft.

6. ***Melothria indica*** Lour. Fl. Cochinch. 35 ; DC. Prodr. iii. 313 ; Naud. in Ann. Sc. Nat. Ser. 4, xvi, 160, with a fig. ; Kurz. in Journ. As. Soc. 1877, pt. ii. 105 ; *M. Regelii* Naud. l. c. ser. 5, v. 35 ; *Aechmandra indica* Arn. in Hook. Journ. Bot. iii. 274 ; Miq. Fl. Ind. Bat. i. pt. i. 658 ; *Bryonia tenella* Roxb. Fl. Ind. iii. 725 ; Clarke in Hook. f. Fl. Brit. Ind. vol. ii, p. 626.

A slender stemed biennial or perennial creeper. Root fibrous, white rather fleshy. Stem and branches numerous, filiform, creeping, pretty smooth. Leaves 1½ by 1½ in., petioled, acuminate or scarcely acute often punctate on both surfaces ; particularly underneath more or less cordate from 3 to 5-angled denticulate, petiole 1 in. Tendrils simple. Flowers axillary, two male and one female together, each on its prominent peduncle, small pure white. Pedicles of males and females about as long as the petioles. Point of the connective short. Filaments 3, from the bottom of the bell of the corolla or calyx, each with a large fleshy lid on each side of which is a single anther crested behind with a tuft of orange coloured hairs. Style filiform. Stigma large, three lobed. Fruit white when ripe ½ in. ellipsoid pointed, many seeded. Seeds strongly margined. This appears exceedingly rare in India ; but it may be doubted whether the next species is a form of this.

Flowers August to October.

Habitat

Sikkim, alt. 3,000 ft. ; C. B. Clarke ; Sylhet in the jheels, H. f.&T. Chittagong, Kurz. A native of China. Distributed from Malaya to the Philippines, China and Japan.

Occurrence

Burma	Kung Tung 4,000, S. Shan States, December 1909, Coll. R. W. MacGregor, I.M.S.
Bengal	Kamhara, E. Mymensing, 5th November 1868, Coll. C. B. Clarke ; Chittagong Aug. 1869, Coll. S. Kurz
Himalaya	Sikkim 3,500 ft., 8-9-75, Coll. G. King ; Rungbee, Sikkim Himalaya 11-8-76, Coll. G. King ; Sikkim 1873, Coll. G. King ; Sikkim 2-10-68, Coll. S. Kurz
Assam	Konoma, Naga Hills 1886, Coll. Dr. D. Prain ; Jotsome, Naga Hills, September 1886, Coll. D. Prain ; Neechoogard 500 ft., Naga Hills, 17th October 1885, Coll. C. B. Clarke
Malay Peninsula	W. Java Fall, S. Kurz ; Sulangora August 18th, 1880 Coll. Dr. King's collector.

7. ***Melothria odorata*** Hk. f. & Thoms. ex C. B. Clarke in Hook. f. Fl. Brit. India ii 626 ; *Melothria leucocarpa* Cogn. l. c. 601 ; *Bryonia odorata* Ham. in Wall. Cat. 6706 A.B.C.

Nearly glabrous, stem often stouter than *M. indica ;* tendrils simple. Leaves 2-3 by 1½-2½ in. more or less cordate entire or somewhat 3-lobed, acute often punctate on both surfaces, petiole 1-1½ in. Male peduncle long somewhat zigzag, with a cluster of pedicles (each ½-¾ in.) at each angle ; female pedicle as long as the petiole. Corolla white, with much hair round the throat. Connective not much produced ; rudiments of ovary in the male flowers globose depressed. Seeds ⅛-⅙ in. not or very obscurely margined. This species has been separated from *M. indica* by the long raceme of the male flowers, which, however, does not essentially differ. The fruit appears very obtuse, the degree of margination of the seeds can hardly be relied upon.

Flowers August to December.

Habitat

North-West Himalaya ; Royle ; throughout the plains of E. Bengal common, and ascending the hills of 7,000 ft.

Var. triloba : lobes of leaf diverlcating sometimes very narrow and long, petiole often shorter than the type. *Bryonia triflora* Wall. Cat. 6707.—E. Bengal, Surma Bank, Griffith (Kew Distrib. No. 2530). The male inflorescence and the fruit are like those of *M. odorata ;* the leaves unlike.

Occurrence

Assam	Jaboca near Naga Hills, December 1898, Coll. Dr. Prain's collector
Wall. Cat.	Nepal 1821, 6706 C ; Goalpara 21st August 1808, 6706 A ; Sylhet 6706 B
N. W. Himalaya . . .	Mussooree 4-5,000 ft., September 1877, Coll. J.F.D.
Bengal	Dacca station, 11th Oct. 1868, Coll. C. B. Clarke.
N. W. Himalaya . . .	Lohba 6,500 ft., Garhwal District, 19th October 1912, Coll. D. Hooper
Sikkim Himalaya . . .	Teesta 1,000 ft., Sikkim 23rd October 1869, Coll. C. B. Clarke
Assam	Kohima 5,000 ft., Naga Hills, 1st November 1885, Coll. C. B. Clarke ; Pippenia 20-1-1882, Coll. H. Collect ; Khasia, Herb. Griffith ; Gauhati, November 1852 ; banks of Kulling, October 1809 ; Sibsagar, October ;
Nicobars	Battimal March 1891, Coll. Dr. Prain
Malay Peninsula . . .	Mount Tancubam Prew, Java, 4-7,000 ft., Coll. T. Anderson

8. ***Melothria zeylanica*** Clarke in Hook. f. Fl. Brit. India. ii. 626 ; *M. deltoidea* Thwaites Enum. 124 ; *Aechmandra deltiodea* Arn. in Hook. Journ. Bot. iii. 274 ; *Bryonia deltoidea* Arn. Pugil 19.

A pretty very slender climber, nearly glabrous. Tendrils simple. Leaves 2 by $1\frac{1}{2}$ in. not lobed little cordate, acute often punctate on both surfaces ; petiole 1 in. Pedicles of both male and females about as long as the petioles. Corolla hairy round the throat ; rudimentary ovary of the male depressed globose. Ovary fusiform ; stigma large, 3-lobed. Fruit $\frac{1}{2}$ in. broad, obtusely trigonus. almost rostrate. Seeds $\frac{1}{8}$ in., packed in three columns. The name *M. deltoidea* is preoccupied by Benth. in *Flora Nigrit.* 368 for a different plant.

Flowers December to July.

Habitat

Ceylon ; common upto 5,000 ft., Walker ; Gardner.

Occurrence

Peninsular India & Ceylong .	Ceylong 5,000 ft., 12-4-59 ; Ceylong to E.P. 16-4-59 ; Devala 3,000 ft., Nilgiris 1884, Coll. J. S. Gamble ; Kadamporai, Anaimalai Hills, 3,300 ft., Nilgiris 1884, 8-12-1913, Coll. C.E.C. Fischer ; Machur, Pulney Dist., 4th July 1897, Coll. A. G. Bourne
W. India	Savantvadi, Bombay, 3rd April 1900, Coll. Dr. Dalgado

9. ***Melothria Wallichii*** Clarke in Hook. f. Fl. Ind. ii, 626 ; *Bryonia odorata* Wall. Cat. 6706 D.

Stem glabrous, tendrils simple. Leaves triangular, not lobed little cordate, sinous scarcely denticulate, scabrous above with flat round glands, slightly hispid beneath. Male raceme nearly as in *M. odorata.* Fruit pedicle $\frac{3}{4}$ in. Fruit rostrate, attenuate at the base, resembling closely that of *M. zeylanica* but rather larger. Seeds nearly $\frac{1}{4}$ in., larger than those of *M. zeylanica* but rather larger. Seeds nearly $\frac{1}{4}$ in., larger than those of *M. zeylanica,* many, oblong very complanate, hardly margined, smooth on the faces.

Habitat

Prome (Burma) ; Wallich.

10. ***Melothria bicirrhosa*** C. B. Clarke in Hook. f. Fl. Brit. Ind. Vol. ii, page 627.

Nearly glabrous ; stem like that of *M. odorata.* Tendrils stout all 2-fid ; leaves 4 by 3 in., deeply cordate, ovate caudate acuminate, petiole 2-3 in. Inflorescence exactly as in *M. odorata.* Male flower altogether of the genus, anthers lateral on the connective which is long produced above them ; rudiment of the ovary depressed globose. Fruit not known. This appears as an excessively developed, *M. odorata.*

Habitat

Burma . . . . . . Griffith (Kew Distrib. No. 2522).

11. **Melothria heterophylla** Cogn. in DC. Monogr. Phan. v. 3, (1881) p. 618 ; Jackson, in Index Kew. v. 3, p. 203 ; *Bryonia umbellata* Klein. in Willd. sp. Pl. v. 4, p. 618 ; Grah. Cat. p. 78 ; Dalz. & Gibs. p. 101 ; *Zehneria umbellata* Thwaites 125 ; C. B. Clarke in Hook. f. Fl. Brit. Ind. vol. ii. p. 625 ; Kurz. in Journ. As. Soc. 1877, pt. ii 105 ; *Zehneria hastata* Miq. Fl. Ind. Bat. v. 1, part 1, p. 656 ; Woodr. in Journ. Bomb. Nat. v. ii (1898) p. 640 ; Watt. Dict. Econ. Prod. v. 6 part 4. p. 355 ; *Karivia umbellata* Arn. in Hook. Journ. Bot. iii 275 ; Miq. 1. c. 661 ; *K. Rheedii* Roem. ; Miq. 1. c. 661 ; *Momordica umbellata* Roxb. Fl. Ind. iii, 710 ; *Bryonia amplexicaulis* Lamk. Dict. i. 496 ; DC. 1. c. 306 ; W.& A. Prodr. 346 ; *B. sagittata* Rheedei and Blume ; DC. 1. c. 305, 306.

Vern. Hind. *Anant-mul ;* Beng. *Kudari ;* Pb. *Bankakra.*

Dioecious ; root perennial, consisting of several tubers ; stems slender, branched, furrowed glabrous. Tendrils simple. Leaves 3-6 in. long, polymorphous, regularly ovate, or 3-5 angled or lobed, or hastate, acute or acuminate, usually cordate at the base, generally scabrid and pale green above, paler or cinereous and reticulately veined beneath, margins remotely denticulate ; petiole $\frac{1}{4}$-$\frac{1}{8}$ in. long pubescent. *Male flowers* subumbellate, 15-20 on a peduncle $\frac{1}{4}$-$\frac{3}{4}$ in. long ; pedicles filiform, $\frac{1}{8}$-$\frac{1}{3}$ in. long. Calyx glabrous ; tube campanulate, rounded at the base, $\frac{1}{6}$-$\frac{1}{4}$ in. long ; teeth minute, subulate. Corolla small, yellowish-white ; segments triangular, acute $\frac{1}{16}$ in. long. Filaments slender subglabrous, $\frac{1}{8}$ in. long. *Female flowers* : peduncles solitary, $\frac{1}{4}$-$\frac{1}{2}$ in. long. Ovary narrowly oblong, glabrous or more or less pubescent, 10-ribbed. Fruit $1\frac{1}{2}$-2 in. long, oblong ovoid cylindric, tapering towards the apex, ribbed, bright-red when ripe. Seeds obovoid or subglobose, scarcely compressed, smooth, white. The leaves are very variable in shape.

Flowers March to July.

Habitat

Throughout India and Ceylon very common. Distributed to Malaya, China, North Australia.

Var. i. Leaves deeply 5-palmate with narrow lobes, scattered glands, young ovary densely velvety, seeds oblong slightly compressed quite smooth and rounded with no trace of a margin. *Bryonia nepalensis* Seringe in DC. Prodr. iii 307 ; Temperate Western Himalaya.

Var. ii. Leaves regularly oval, margin denticulate or crenate dentate. In Eastern India (Wight n. 1122 part ; Ritchie n. 308/2 ; Hiigel n. 2417) ; in Assam (Simouns ; Masters) ; in Sylhet (Wallich n. 6705 part) ; in Mont. Khasia (Hook. f. & T.) in Sikkim (Hook. f.) ; in East Bengal (Griffith n. 2526/1 part) ; in Ceylon (herb. Berol) ; in Java (Blume).

Var. iii. Leaves ovate, angular or lobed. *Bryonia simosa* Wall ! 1. c. in Eastern India (Wallich n. 6716 part ; Wight n. 1121 ; Royel) ; in Nilgiri Hills (Hohenacker n. 1506) ; in Mysore (Hiigel n. 435) ; in Assam (Jenkins) ; in Coromandel (Belanger n. 307) ; in Ceylon (Thwaites n. 1619 ; Fraser).

Var. iv. Leaves ovate-oblong, denticulate Eastern India (Lambert ; Wallich n. 6705, R.S. 3 ; Roxburgh ; Wight n. 1129 part ; Hugel n. 2822 & 4502 ; Thomson) ; in Assam (Jenkins) ; in Ceylon (herb. Lugd.-Bat.) ; in Java (Blume).

Var v. Leaves deeply 3-5 lobed, lobes subequal, triangular or lanceolate.—*Bryonia Teedonia* Roxb. 1. c. In Eastern India (Roxb. ; Wight n. 1122 part, 1129 part ; Heyne) ; in Sikkim (Hooker f.).

Var. vi. Leaves deeply 3-5 lobed, lobes subequal, sublinear. In Eastern India (Wight n. 1122 part) ; in Nepal (Wallich n. 6705 F. part).

Var. vii. Leaves hastate, lobes entire terminal lobe oblong or triangular, basal one divergent. Northern India (Stewart) ; in Sikkim (Trentler) ; in Mount Khasia (Hook. f. & T.) ; in East Bengal (Griffith n. 1526, part) ; in Java (Horsefield ; Zolinger n. 669).

Var. viii. Leaves hastate, lobes dentate or crenulate, terminal ones oblong or triangular, basal ones divergent. In Eastern India (Roxburgh ; Royel ; Stewart) ; in Nepal (Wallich n. 6705 F. part) ; in Eastern Bengal (Griffith n. 2526, part) ; in Coromandel coast (Belanger n. 307) ; in Ceylon (Thwaites n. 1619 part).

Var. ix. Leaves hastate, lobes entire, terminal lanceolate or linear-lanceolate, basal ones parallel or convergent. *Bryonia sagittata* Bl. l. c.—*Zehneria connivens* Miq. l. c. Eastern India (Wight n. 1129 part) ; in Mount Khasia (Hook. f. & Thomson) ; in Sikkim (Hooker. f.) ; in East Bengal (Griffith n. 2526, part) ; in Java (Blume ; Horsfield).

Var. x. Leaves hastate, lobes entire, terminal one lanceolate or linear lanceolate, basal ones divergent.—*Bryonia Rheedii* l. c. East India (Jacuemont n. 898, A ; Ritchie) ; in Tenasserim (Falconer) in Punjab (Aitchison n. 1056) ; in Mont. Khasia (Hook. f. & Thom.) ; in Java (Blume & Zollinger n. 669 part).

Var. xi. Leaves hastate, lobes sublinear, lobular, lateral ones divergent. Eastern India (Hugel n. 4965 in Herb. vindol).

Var. xii. Leaves hastate, lobes sublinear, entire lateral ones divergent. In Nepal (Hornimann in herb. Berol) ; in Ceylon (Thwaites n. 3506 in herb. DC. Boiss. Mus. Par. Kew).

Medicinal use

Dymock remarks, " Its medicinal properties do not appear to be known to European writers on Indian Materia Medica, nor does it appear to have had a place in the Sanskrit Materia Medica. In Konkan the juice of the root with cumin and sugar is given in cold milk as a remedy for spermatorrhoea, and the juice of the leaves is applied to parts which have become inflamed from the application of the marking-nut juice. As a *paushtik* or restorative and fattening medicine, roasted onions, gometta root, cumin sugar and ghee are given or gometta only with milk and sugar " (*Materia Medica West Ind.*). Food : " The ripe and unripe fruits are eaten by the natives, as are also the roots when boiled " (Roxb. Campbell). In Bombay the fruit is eaten together with that of *Capparis zeylanica* Linn.

Occurrence

N. W. Himalaya	Coll. P. W. Mackinnon ; Tons Valley 4-5,000 ft., Tehri Garhwal District, 4th June 1894, Coll. J. F. Duthie.
Bengal	Alipur Duars, 1891, Coll. E. A. Heawood.
Orissa	Baripada vern. Bankundi, Myurbhunj District, 30th June 1912, Coll. D. Hooper.
Burma	Mountain stream 500 ft., Upper Chindwin District, 19th October 1926 ; Inle Lake, Southern Shan States, 6th March 1917, Coll. N. Annandale ; Maymyo plateau 3,500 ft., Mandalay District, 10th May 1909, Coll. J. H. Lace ; Taba dowa, Upper Burma July 1891, Coll. Abdul Haque ; Moulmein, Tennesserim, May 1911, Coll. A. Meebold ; Keng Tung 2,000 ft., Southern Shan States, July 1909, Coll. Capt. R. W. MacGregor.
Bihar	Top of Parashnath, 23rd September 1858.
Bengal	Rich soil, Kodala Hill 30 miles from Chittagong, October 1887, Coll. Dr.King's collector, Badal Khan.
Burma	Nwamadanug Hills, Minbu District, Upper Burma, 20th March 1903, Coll. Aubert and Gage ; Fort Stedman, 1894, Coll. Abdul Khalil ; Khoni, Upper Burma, May 1888, Coll. J. C. Prazer ; Chu ku plains, Tenasserim, 27th April 1877, Coll. Geo. Gallatly ; Martaban, Coll. S. Kurz ; Toladowa, Upper Burma, July 1891, Coll. Abdul Khalil ; near Maymyo 4,000 ft., April 1888, Coll. N Manden ; Plumado, above the village 4,000 ft., April 1888, Pegu, Coll. S. Kurz ; Amherst, 30th March 1849, Coll. Falconer ; District, Memon, Myitkyina Ynnan Expedition, 8th June 1868, Coll. D. J. Anderson ; Sittang side Pegu, Coll. S. Kurz.
Peninsular India and Ceylon	Mundomurhi, Travancore State, 27th August 1913, Coll. C. C. Calder and M. S. Ramaswami ; Manuzhathora, Travancore, 4th October 1912, Coll. M. Rama Rao ; Mundagamurhi, Travancore, 27th August 1913, Coll. M. Rama Rao ; Perumal 5,500 ft., Madras, 4th February 1913, Rev. August, Saulieres ; Dachuru, Nelore District, about 250 ft., 12th August 1917, Coll. C. E. C. Fischer ; Mysore and Carnatic, Coll. G. Thomson ; Travancore, Coll. J. F. Bourdillon ; Bhimandidu, Mysore Province, 30th March 1905, Coll. C. A. Barber ; Koni, 200 ft., Travancore, 19th December 1894 ; Coll. J. F. Boudillon, Madras ; Madras Presidency, Coll. M. S. Ramaswami ; Bombay ; Gungagudem, Godavari District, 11th August 1914, Coll. M. S. Ramaswami ; Karwar, N. Kanara District, Bombay, June 15, 1883, Coll. Dr. Ritchie ; Trichur, Cochin, Madras, September 1884, Coll. J. S. Gamble ; Malabar, Konkon, tropical region, Coll. Stocks Law

Assam	Therria Ghat, Khasia and Jaintia Hills, 14th October 1910, Coll. D. Hooper; Wood north of Circuit house, Haflong, 2,500 ft., N. Cachar 1-VIII, 1908, Coll. W. G. Craib; Haflong 2,675 ft., W. Cachar, 10th August 1908, Coll. W. G. Craib, near Maoryng Kueng, 4,500 ft., Khasia Hills, 8th June 1911, Coll. I. H. Burkill, and S. C. Banerjee; Mount Khasia 1-4,000 ft., Coll. J. D. H. & T. T., Gauhati, May 1831, East Bengal; Coll. Griffith, Khasia, Coll. Oldham, Konoma, May 1895; Coll. Reporter of Economic Products of the Government of India; Kohima, 4,750 ft., Naga Hills, 22nd October 1885, Coll. C. B. Clarke; Kohima, 30th October 1885, Coll. C. B. Clarke; Khongui Hill 6,000 ft., Manipur (on the Eastern frontier of India), April 8 1882, Coll. George Watt.
Bengal	Dinajpur, March 1897, Coll. Reporter of Economic Products Government of India; Sibpur IX, 64, Coll. S. Kurz.
E. Himalaya	Lachung valley 7,500 ft., Sikkim Himalaya, 14th September 1892, Coll. Col. G. A. Gammie; Ryang, 23rd August 1876, Coll. G. King; Kalimpong 4-5,000 ft., July 18 1914, Coll. Thonton Ripley; Ryang, 2,000 ft., 12 May 1874 Coll. G. King; towards Tungbo, 20th June 1857, Sikkim Terai, Coll. S. Kurz; Sikkim 1-2,000 ft., Coll. J. D. H.; Rungo valley, Coll. S. Kurz; Mungpu—British Sikkim, August 1903, Coll. A. C. Harttess.
Central India	Ajmere, Abu Sirohi, Rajputana, June 1868, Abu 4,000 ft., Coll. G. King, M.B.; Guna, 9th August 1867, Coll. G. King; Abu, Rajputana, Coll. Major Roberts.
N. W. Himalaya . . .	Simla, 4-7,000 ft., Coll. T. T.; Ganges valley near Muklea, 8-9,000 ft., 13th August, Coll. J. F. Duthie; Hazara, N. W. F.P., 3,500-5,000 ft., Coll. Stewart; Dippi, 8,000 ft., Coll. Dr. Brandis; N. E. of Simla, Coll. Dr. Stoliezka; N. W. India Hb. Royle, September 4th 1880, Coll. J. E. T. Aitchison.
Bihar	Sahibganj, Santal Parganas, Bihar, 22nd May 1870, Coll. C. B. Clarke.
....	Parasnath Hill, Hazaribagh District, 14th November 1858.
Gangetic Plain	1,000 ft., Moradabad, U. P. 8/45, Coll. T. T.; Moharajaganj, Gorakhpur District U. P. vern. Birhani, 6th October 1902, Coll. Kalka Prosad.
Bengal	Chandernagar, August 1902, Coll. Abu Hossein; Chandpur, Tipperah, 26th October 1898, Coll. D. Hooper.
Orissa	Baripada Vern. Bau Koadrie, Maymurbhanj, 3rd-December 1911, Coll. D. Hooper.
Central India	Chanda, District Chanda, Central Province, 6th February 1904, Coll. Reporter of Economic Products, Government of India.
E. Himalaya	Great Rungiet, Sikkim, 1,800 ft., May 1862, Coll. T. Anderson, M.D.; Sikkim, 1872, Coll. G. King, M.B.
Wall. Cat.	Dindigul, Madura District, Madras, 11th December 1826, Tavoy, No. 6705 S., Tavoy Burma, 28th August 1827, n. 6705 S., Sylhet, Assam, No. 6705, 6705 N., 6705 O, 6705 E or F., Gorakhpur, U. P., 6705 C, 21st April 1814, Jalpaiguri, March 1809, 6705 D.
Java Pen.	Java, Coll. Bl.

18. Kedrostis

Kedrostis, Medic. Phil. Bot. 2, p. 69 (1791). Meisn. Gen. p. 126 (91); Endl. Gen. pl. p. 935, n. 9124; Arn. in Hook. Journ. of Bot. 3, p. 273; Wight in Ann. and Mag Nat. Hist. 8, p. 267; Roem. Syn. fasc. 2, p. 8, 22; Endl. l. c. n. 9125; Roem l. c. p. 8, 23.—*Rhynchocarpa* Schrad. Reliq. l. c. (1838) 403; Endl. l. c. n. 5129; Meisn. Gen. comm. p. 356; Naud. in Ann. Sc. nat. ser. 4, v. 12, p. 146; Benth. et Hook. Gen. Pl. 1, p. 831; Harv. Gen. South Afr. Pl. edit. 2, p. 126; Boiss. Fl. Orient. 2, p. 762; Hook. f. in Oliv. Fl. trop. Afr. 2, p. 627.

Prostrate or scandent herbs; root perennial. Tendrils simple. Leaves entire or lobed. Flowers small, monœcious (rarely diœcious). Male flowers racemose or corymbose. Calyx tube campanulate, usually glabrous within; lobes 5 short. Corolla rotate, 5-partite. Stamens 3 (rarely 5), inserted in the calyx tube; filaments short, glabrous; anthers short, glabrous, one 1-celled, the others 2-celled (or when 5 all 1-celled), free or slightly cohering, the cells straight or slightly curved, the connective usually 2-fid or 2-partite; produced beyond the cells. Rudimentary ovary 0 or granduliform. Female flowers subsessile, solitary of aggregated, shortly pedicelled. Calyx and corolla as in the male. Rudimentary stamens 0 or 3, very small. Ovary usually ovoid, beaked 2-3-placentiferous; ovules few, horizontal; style sometimes obscurely surrounded by a disk at the base; stigmas

2 or 3. Fruit baccate, ovoid, usually rostrate. Seeds usually few, tumid, margined; testa usually crustaceous smooth. Distrib. Tropical and sub-tropical Asia and Africa; species 11.

Kedrostis rostrata Cogniaux. in DC. Monogr. Phan. v. 3 (1881), p. 636; Jackon. in Index Kew. v. 2, p. 4; *Rhynchocarpa fœtida* C. B. Clarke in Hook. f. Fl. Brit. Ind. 2, p. 627 (partly); *R. rostrata* Naud. in Ann. Sc. Cat. Ser. 4, v. 16, p. 177; Kurz. in Journ. As. Soc. Beng. (1877), part 2, p. 105; Trim. Fl. ceyl. v. 2, p. 258; Woodr. in Journ. Bomb. Nat. v. ii (1898), p. 640; Watt. Dic. Econ. Prod. v. 6, part 1, p. 502; *Aechmadra rostrata* Arn. in Hook. Journ. Bot. v. 3 (1841), p. 274; Dalz. & Gibs., p. 100; *Bryonia pilosa* Roxb. Hort. Beng. p. 104; Grat. Cat. p. 248; *Bryonia rostrata* Rottl; in Willd. Spec. pl. 4, p. 616; Ser. in DC. Prodr. 3, p. 304; Wight & Arn. Prodr. 1, p. 346.

Scandent, monœcious; stems slender, branched, angled, scarcely hairy. Tendrils simple, filiform glabrous. Leaves $\frac{3}{4}$ by 2 in. long and as broad as long, membranous, orbicular in outline, bright green, hairy and more or less scabrid on both sides, margins entire or distinctly toothed, cordate at the base. Sometimes 5-angled or sublobate, the lobes subacute, apiculate; petioles $\frac{1}{2}$-$1\frac{1}{2}$ in. long, hairy. *Male flowers:* peduncles filiform $\frac{1}{4}$-$\frac{3}{4}$ in. long, 2-4 flowered at the apex; pedicells capillary $\frac{1}{10}$-$\frac{1}{4}$ in. long, usually bracteolate at the base; teeth minute. Corolla pale yellow segments oblong lanceolate, acute $\frac{1}{6}$-$\frac{1}{5}$ in. long pubescent. *Female flowers;* peduncles $\frac{1}{10}$-$\frac{1}{3}$ in. long. Ovary oblong, beaked pubescent. Fruit subsessile, deep red about 1 in. long, ovoid, tapering into a long narrow beak, pubescent. Seeds $\frac{1}{6}$ in. long oboid, with a narrow sharp wing, brown.

Flowers May to October.

Habitat

Gujarat, Dalzell; Deccan Peninsula, Rottler, Wight; Malabar Hills, Stocks; Dr. Ritchie; Ava, Wallich. Distributed tropical Africa and Natal.

Medicinal use

Speaking of this plant Ainslie says, " The fruit as it appears in the bazars, is about the size of a finger and of a light grey colour; it has no particular smell, but slightly sweetish and mucilagenous taste, it is prescribed internally, in electuary, in cases of piles; in powder it is sometimes ordered as a demulcent in humoral-asthma; dose of the electuary two tea spoonful thrice daily ".

Occurrence

Pen. India	Gingee, S. Arcot, District Madras, 1st October 1926, Northern Division, January 1852, Kodaikanal Ghat, Madura District, Madras; Pulneys, 7th July 1901, Coll. Bourne; in grass on a hill near Deverayi, 1,800 ft., July 1918, Coll. L. J. Sedgwick & T. R. D. Bell, Bodinaikanur, District Madura, December 1910, Coll. A. Meebold; Bombay, N. Dalzell.
C. I.	Ali Rajpur, 20th May 1897, Coll. Reporter of Economic Products to the Government of India; Vern. *Mirchaya kanda*.

19. Cerasiocarpum

Cerasiocarpum, Hook. f. in Benth. et. Hook. Gen. Plant I, p. 832; Baill. Dict. de Bot. 1, p. 702; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 628.

Climbing glabrous herbs; tendrils simple. Leaves long petiolate, oblong, cordate, nearly entire. Flowers very small, monœcious; male peduncle carrying a few clustered flowers at the top; female flowers sessile, solitary, often in the same axil with the male. *Male:* calyx tube short campanulate with 5-minute teeth; corolla 5-partite; stamens 3; anthers subsessile, distant, one 1-celled, two 2-celled; cells oblong, lateral on the connective which is not produced; rudiment of the ovary 0. *Female:* calyx and corolla as in the male; ovary ovoid; disc. 0, stigma 3; ovules 3, horizontal; placentas vertical; fruit ellipsoid, subsessile, indehiscent, without a beak; seeds 2-6, smooth, slightly compressed.

Cerasiocarpum zeylanicum Hook. f. in Benth. & Hook. f. Gen. i. 831; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 629; *C. Benettii* Cogn. in Monographia Phanarogamarum. Vol. III, p. 729; *Bryonopsis Benettii* Miq., Fl. Ind. Bat. part 1, p. 657; *Aechamandra zeylanica* Thw., Enum. pl. zeyl., p. 125.

Leaves 3-6 in. membranous obtuse or acute triangularly oblong or hastate, base broadly emerginate cordate, margin entire or undulate denticulate; petiole $\frac{1}{2}$-$1\frac{1}{2}$ in. Flowers $\frac{1}{4}$-$\frac{1}{3}$ in. diam., yellow. *Male flowers:* calyx tube, sparingly pilose, about 1 in. long and about 1-$1\frac{1}{4}$ in. broad. Petals broad acuminate 5-nerved with dense glandular hairs about 1 in. long and less than an inch broad. Stamens-filaments about $\frac{1}{6}$-$\frac{1}{4}$ in. long, anthers $\frac{1}{4}$-$\frac{1}{3}$ in. long. *Female:* calyx tube campanulate, $1\frac{1}{5}$ in. long and $\frac{3}{4}$ in. broad. Petals ovate oblong, $1\frac{1}{5}$ in. long. Ovary glabrous about an inch long and $\frac{1}{2}$ in. in diameter. Seeds $\frac{1}{6}$-$\frac{1}{4}$ in. diam., little compressed, incompletely margined, 2-6 in each fruit.

Flowers August to November.

Habitat

Ceylon, alt. 3-5,000 ft., Thwaites; Java; Sumatra; in India orient.

Occurrence

Ceylon	Central Province at an elevation of 3-5,000 ft., Coll. Thwaites; Antani, November 1858.
Sumatra	Gœnasty nay Lampay, 12th August 1880, Coll. H. O. Forbes.

20. Corallocarpus

Corallocarpus Welw. in Benth. and Hook. Gen. Plant 1, p. 838 (1867) and Sert. Angol. in Trans. Linn. Soc. 27, p. 32; Hook. f. in Oliv. Fl. trop. Afr. 2, p. 565; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 627; Cooke Fl. of Bombay 1901-03 vol. I, p. 543.

Prostrate or climbing herbs. Tendrils simple. Leaves roundish or cordate, lobed or palmate. Flowers minute, monoecious. Male flowers croweded at the apex of along peduncle. Calyx-tube broadly campanulate; lobes, short. Corolla 5-partite; segments ovate-oblong. Stamens 3, free, inserted on the calyx tube; filaments very short, anthers glabrous, entire or partite, one 1-celled, the others 2-celled, the cells straight, the connective produced or not, often bifid. Rudimentary ovary 0 or minute. Female flowers sessile or shortly pedicelled, solitary or fascicled, sometimes subspicate. Calyx and corolla as in the male. Rudimentary stramens 0 or minute. Ovary ovoid, beaked, 2-3 celled; ovules few, horizontal; style straight, without a basal disk stigma 3 (rarely 2-4) lobed. Berry fleshy ovoid or ellipsoid, rostrate or obtuse, operculately dehiscent near the base. Seeds few, obovoid or subglobose, tumid. Distrib. India and Tropical Africa. Species 15.

Key to the species

Seeds globose compressed hardly margined; fruit ellipsoid sessile, suddenly narrowed into a short back; stem stout	1. *C. velutinus.*
Seeds ellipsoid or pyriform; stem slender; Female flowers usually fascicled or subspicate; seeds not margined	2. *C. conocarpa.*
Female flowers usually solitary; seeds slightly margined	3. *C. epigaeus.*

1. ***Corallocarpus velutinus*** Benth. & Hook. f. Gen. Pl. v. 1, Fl. B. I. v. 2, p. 628; Woord. in Journ. Bomb. Nat. v. ii (1898), p. 640; Hook. Bomb. Fl. vol. i, p. 544; *Aechenandra velutina* Dalz. & Gibs., p. 100.

A stout climber; root fibrous; stem stout, angular, hairy, deeply grooved, not much branched. Tendrils very long, striate, simple. Leaves fleshy, suborbicular in outline, 2-3 in. long and as broad as long, pale green and at first softly villous, finally scabrid above, tomentose and ashy-grey beneath, cordate or subtruncate at the base, deeply palmately 3-5 lobed, the lobes rounded or oblong, sometimes tubulate, irregularly denticulate; petiole stout, $1\frac{1}{2}$-2 in. long, densely hairy. *Male flowers* in 15-20 flowered racemes at the top of a hairy slender peduncle 2-4 in. long; pedicles filiform $\frac{1}{10}$-$\frac{1}{5}$ in. long; calyx shortly hairy; tube sub-hemispheric, $\frac{1}{18}$ in. long; teeth narrowly triangular, less than $\frac{1}{20}$ in. long. Anthers subsessile; connective scarcely produced, bifid. *Female flowers* fascicled, subsessile. Fruit $\frac{3}{4}$ in. long, including the beak, sessile ellipsoid, suddenly narrowed into a beak almost $\frac{1}{5}$ in. long, red when ripe, finely velvety. Seeds $\frac{1}{8}$ in. in diam., globose, margined.

Habitat

Sind, Dalzell ; Distrib. Persian Gulf and tropical Africa.

Occurrence

W. India . . . . . . Mihrat Tangi, 3,500 ft., Beluchistan and assigned District, Coll. J. H. Lace.

2. ***Corallocarpus conocarpus*** C. B. Clarke, in Hook. f. Fl. B. I. v. 2 (1878), p. 628 ; *Aechandra conocarpa* Dalz. and Gibs. Bomb. Fl., p. 100 ; Hook. Bomb. Fl. v. i, p. 544.

Climbing, monœcious ; stems slender, striate, glabrous ; tendrils simple, slender, glabrous. Leaves 2-$2\frac{3}{4}$ by $1\frac{1}{2}$-$2\frac{1}{2}$ in. pale green above ash coloured beneath both surfaces and especially the lower, clothed with minute white hairs, scarcely scabrid, cordate, at the base, deeply palmately 3-5-lobed, the lobes oblong lanceolate, acute or acuminate, the terminal lobe the longest much contracted at the base ; petioles $\frac{3}{4}$-$1\frac{1}{4}$ in. long, slender, rugulose. *Male flowers* 6-15 at the apex of a slender glabrous peduncle $\frac{1}{2}$-$1\frac{1}{4}$ in. long ; pedicles filiform $\frac{1}{24}$-$\frac{1}{12}$ in. long. *Female flowers* fascicled or subspicate. Fruit glabrous conical-oblong, not suddenly contracted into the beak, orange red except the cupshaped base which remains green. Seeds pyriform, turgid $\frac{1}{8}$-$\frac{1}{6}$ by $\frac{1}{12}$-$\frac{1}{10}$ in., dark brown (nearly black), margined.

Flowers June to August.

Habitat

Gujarat near Malpor and Gundar ; Dalzell ; also in Stocks collection probably from Sind. Distributed to Central Africa. W. India : Sind ; Sambal, Dharwar, Bombay, September 4, 1889, Coll. W. A. Talbot.

3. ***Corallocarpus epigaeus*** C. B. Clarke, in Hook. f. Fl. B. I. v. 2 (1879), p. 628 ; Trin. Fl. Ceyl. v. 2, p. 258 ; Woodr. in Journ. Bomb. Nat. v. ii (1898) p. 641 ; *Byronia epigœa* Rottl. in Nov. Act. Soc. nat. scrut. Berol 4, p. 212 (1803) ; Willd. spec. Pl. 4, p. 619 ; Spreng. syst. veget. 3, p. 16 ; Wight Arn. Prodr. 1, p. 346 ; Wight Icon. tab. 503 ; Walp. Report 2, p. 198 ; non Bl. ; *B. glabra* Roxb. Hort. Beng. p. 104, Fl. Ind. 3, p. 725 ; *B. palmata* Wall. List n. 6711 D, non Lin. ; *Aechenandra epigœa* Arn. in Hook. Journ. of Bot. 3, p. 274 ; Rom. Syn. mon. fasc. 2, p. 33 ; Thw. Enum. pl. zeyl. p. 125 ; Dalz. & Gibs. Bombay Fl. p. 100 ; *Rhynochocarpa epigœa* Naud. in Ann. Sc. nat. ser. 4, v. 16, p. 178.

Prostrate or climbing, monœcious ; root large ; turnip shaped ; stems slender, grooved, zigzag, glabrous ; tendrils simple, slender glabrous. Leaves suborbicular in outline, $\frac{3}{4}$-3 in. long, usually a little broader than long, light green above, paler beneath, shortly roughly hairy on both surfaces, deeply cordate at the base, angled or more or less deeply 3-5-lobed, the lobes usually lobulate and obtuse, sometimes apiculate more or less irregularly dentate on the margins ; petioles $\frac{3}{4}$-$1\frac{1}{2}$ in. long, glabrous. *Male flowers* small, 5-15 at the apex of a straight stiff glabrous peduncle $1\frac{1}{2}$-$2\frac{1}{2}$ in. long ; pedicles filiform, $\frac{1}{24}$-$\frac{1}{12}$ in. long. Calyx slightly hairy ; tube $\frac{1}{16}$ in. long, slightly rounded at the base, teeth minute, erect, distant, subulate. Corolla greenish yellow ; segments $\frac{1}{24}$ in. long. Anthers yellow ; connective green, produced beyond the cells, bifid. *Female flowers* usually solitary ; peduncles short stout, glabrous. Fruit stalked $\frac{1}{2}$-1 in. long including the beak, ellipsoid or ovoid suddenly contracted into a slender beak $\frac{1}{4}$ in. long, scarlet in the middle, the base and beak green circumcisely dehiscent at the junction of the green and red portions near the base. Seeds 6-9 in. orange coloured pulp, pyriform, $\frac{1}{8}$-$\frac{1}{6}$ by $\frac{1}{12}$-$\frac{1}{10}$ in. turgid, brown, with a whitish corded margin.

Flowers June to August.

Habitat

Punjab, Rawalpindi, J. E. T. Aitchison ; Sind and Gujarat, Dalz. ; Deccan Peninsula, Rottler ; Wight ; Belgaum, Ritchie ; Ceylon, Thawaites.

Medicinal use

" The root is of varying thickness and length and much resembles that of *Momordica dioica*, being in shape not unlike a badly grown turnip, but much larger ; externally it is yellowish white

and marked with red circular rings; the taste is bitter mucilaginous, and subacid when cut it exudes a viscid juice, which soon hardens into an apalescent gum" (Dymock*). A drug valued by the people of India as a alterative tonic useful in syphilitic cases. According to Ainslie† the Vydians of South India esteem the merits of this drug. They prescribe it in later stages of dysentery and old venereal complaints. It is usually administered he says "in powder, which is of very pale colour, in doses of a pagoda (about a drachm) weight in the twentyfour hours and continued for eight or ten days together; this quantity generally produces one or two loose motions. The root when dried very much resembles the *columba root*, to which it apporoaches also in medicinal qualities;" Ainslie also states that for external use in chronic rheumatism it is made into a liniment with cumin seed, onion, and castor oil. It is considered an anthelmintic and deobstruent, and in the Deccan and Mysore it enjoys the reputation of being a valuable remedy for snake bite, being administered internally to the bitten part. The authors of the Pharmacopœia of India agree with Ainslie that this drug deserves to be more carefully examined and its properties tested.

Occurrence

Pen. India	Coimbatore, Trichonopoly, 3rd September 1878; Coll. G. King, Kamalepore September 1910; Coll. A. Meebold, 1,000 ft., Coimbatore District; Coll. C, E. C. Fischer, Lower Pulney, 1,500 ft., 27th September 1913; Coll. Rev., Aug. Sauliers, Bailur, 3,800 ft., Coimbatore District, 22nd August 1905; Coll. C. E. C. Fischer, Hills East of Rajampet, 1,200 ft., Cuddapah District, February 1883; Coll. G. S. Gamble, Malabar, Konkan, Bombay; Coll. Stocks, Law etc.
Wall. Cat.	6711, 6709 B, 6709 A, 6709 C.
Gangetic Plain	Banda, U. P., common, 7th May 1901; Coll. Mrs. A. S. Bell, vern. *Indoran*, fruit poisonous, Jumna ravines near Agra, 31st December 1885; Coll. J. F. Duthie.
Bengal	W. Bengal; Coll. S. Kurz.
Central India	Wasali, Buldana Ditrict, Berar, 23rd September 1909; Coll. I. H. Burkill, Seoni, Chanda District, Central Province, November 1902.

21. Blastania

Blastania Kotschy et Peyr. Pl. Tin. p. 15 (1865-1866), edit. Kanitz. p. 21; *Ctenolepis* Hook. f. sec. Naud. in Ann. Sc. Nat., ser. 5, v. 6, p. 12 (1866, non DC. Notar 1847); *Ctenolepis* Hook. f. in Benth. and Hook. Gen. Plant. 1, p. 832 (1867) and in Oliv. Fl. trop. Afr. 2, p. 557; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 629; Sicyi. *Zehneriæ* and *Bryoniæ* Spec. Auct.; *Zehneriæ* sact. *Bracteria* Stocks in Hook. Kew. Journ. of Bot. 4, p. 148.

Prostrate or scandent, annual herb. Tendrils simple. Leaves digitalely 5-7-lobed or partite. Bracts stipuliform, in axils of the leaves, toothed or pectinately cilate. Flowers minute, monœcious. *Male flowers* racemose, on slender pedicles. Calyx-tube short, campanulate; lobes 5, subulate, very small. Corolla rotate, deeply 5-partite. Stamens 3, inserted on the calyx tube, free; filaments remote, very short; anthers small, one 1-celled, the others 2-celled, the cells short, straight, the connective not produced. Rudimentary ovary 0. *Female flowers* solitary in the same axils as the male; peduncles short. Calyx and corolla as in the male. Staminodes 0. Ovary ovoid, 2-3 placentiferous; ovules few, horizontal; style columnar without a basal disc; stigma 2 (rarely 3). Fruit fleshy, globose or obliquely subquardrate. Seeds few, ovoid, much compressed or boat shaped, the margins obtuse or acute; testa smooth.

Distribution Tropical and subtropical Asia, Tropical Africa; species 2.

Key to the species

Fruit ellipsoid or globose	1. *B. fimbristipula.*
Fruit obreniform or hammer shaped	1. *B. Garcinia.*

1. ***Blastinia fimbristipula*** Kotschy. et Peyr., Pl. Tin. p. 15, tab. 7, edit. Kuitz., p. 22; *Bryonia fimbristipula* Fenzl., in Kotschy Iter. Nutic. n. 205, 231 (1841), in flora, 1844, p. 313;

* Dymock, W-(1885). *Materia Medica West India*, 353
† Ainslie, W-(1826). *Materia Medica* 2,158

Schweinf. Fl. Aethiop., p. 250 ; *Zehneria cerasiformis* Stocks in Hook. Kew. Journ. of Botany 4, p. 149 ; Walp. Ann. 4, p. 855 ; Dalz. and Gibs. Bomb. Fl. p. 100 ; Aitch. Pb. & Sind Pl. p. 65 ; *Ctenolepis cerasiformis* Hook. f. in Oliv. Fl. trop. Afr. 2, p. 558 ; C. B. Clarke in Hook. f. Fl. Brit. Ind. 2, p. 630.

An extensive climber ; stems subfiliform, elongate, much branched, grooved and angled, glabrous, smooth or slightly scabrid. Tendrils slender, elongate, striate, simple. Leaves membranous, $1\frac{1}{2}$-4 in. long and broad, scabrid on both surfaces with white spots, usually 3-partite (rarely 5-lobed), the segment ovate oblong or lanceolate, acute narrowed at the base, denticulate or crenulate, the lateral segments more or less 2-lobbed, the intermediate segment entire or 3-lobed often with a long mucro ; petioles $\frac{3}{4}$-$1\frac{1}{2}$ in. long, slender grooved, hirsute, at length scabrid with white spots. Stipular bracts $\frac{1}{4}$-$\frac{1}{2}$ in. long, orbicular, reniform or dimidiate, scabrid with minute white spots, ciliate with hairs as long as the breadth of the bract. *Male flowers* 5-10 at the apex of a glabrous filiform peduncle $\frac{3}{4}$-$1\frac{1}{2}$ in. long ; pedicles ebracteate $\frac{1}{20}$-$\frac{1}{80}$ in. long. Calyx teeth minute. Corolla minute ; segments ovate-oblong, obtuse, spreading. *Female flowers* solitary ; peduncles short. Fruit subsessile, globose scarlet glabrous, $\frac{1}{2}$ in. in diam. Seeds 2, ovoid, $\frac{1}{3}$ in. long, $\frac{3}{16}$-$\frac{1}{4}$ in. broad ; smooth yellowish grey, convex on one side, deeply concave on the other edge sharp.

Habitat

Sind, Stocks ; Gujarat, Dalzell.—Distrib. Tropical and Southern Africa.

W. India . . . . . . Sind, Bombay ; Coll. Stocks.

2. ***Blastania Garcini*** Cogniaux. in DC. Monogr. Pyan. v. 3 (1881) p. 629 ; Jackson. in Index Kew, v. 1, p. 311 ; *Ctenolepis Garcini*, C. B. Clarke, in Hook. f. Fl. Brit. Ind. v. 2, p. 629 ; *Byronia triloba* Lour. Fl. Cochinch. 2, p. 594, edit. Willd. 2, p. 731 (non Thunb.) ; *B. agrestis* Ræusch. Bot. edit. 3, p. 283, *B. stipulacea* Willd., Spec. 4, p. 620 (excl. var.) ; Ser. in DC. Prodr. 1, p. 344; *B. reniformis* Roxb., in E. ind. Comp. Mus. tab. 468 in ed. ex. W. Arn. ; *Zehneria Garcini* Stocks, in Hook. Kew. Journ. of Bot. 4, p. 149 ; Walp. Ann. 4, p. 855 ; Thw. Enum. pl. zey. p. 125 ; Dalz. & Gibs. Bombay Fl. p. 99 ; *Ctenolepis Garcinis* Naud. in Ann. Sc. Nat. ser. 5, v. 6, p. 13.

Climbing ; stems slender, elongate, striate, branched, glabrous. Tendrils capillary. Leaves membranous, 1-2 in. long and broad, at first hisrute afterwards scabrid with white spots, deeply 3-5-lobed, the lobes usually obovate, obtuse or acute, constricated at base, denticulate or crenately toothed, the intermediate lobes scarcely longer than the others, mucronate ; petioles $\frac{1}{2}$-$1\frac{1}{2}$ in. long, slender, striate, shortly hirsute, at length scabrid. Stipular bracts $\frac{1}{6}$-$\frac{5}{16}$ in. long, ovate or rotundate, shortly hairy, fringed on the margin with long filiforms cilia. *Male flowers* yellowish white, 3-4 at the apex of a slender peduncle, less than $\frac{1}{2}$ in. long ; pedicles $\frac{1}{24}$-$\frac{1}{12}$ in. long. *Female flowers* solitary on very short peduncles. Fruit broader than long, $\frac{1}{6}$-$\frac{1}{4}$ by $\frac{1}{3}$-$\frac{3}{8}$ in., bright red, glabrous inversely subreniform or hammer shaped. Seeds $\frac{1}{4}$-$\frac{1}{3}$ by $\frac{1}{8}$ in., oblong yellowish-grey, rounded at the apex, slightly attenuated at the base, with a deep pit on one face convex on the other, the edge *thick and obtuse.*

Flowers September to December.

Habitat

Bundelkhand, Edgeworth ; Deccan Peninsula, Rottler ; Ceylon Thwaites.

Medicinal use

Atkinson says that the fruit, seeds and roots are used in medicine.

Occurrence

Peninsular India	Northern Division, Bodinaikanur, Madura, December 1910 ; Coll. A. Meebold Ahmadnagar, Bombay, 1,800 ft., September 1919 ; Coll. L. T. Sedgwick & T. R. D. Bell, Biccavol, Godavery Delta, 24th December 1907 ; Coll. Dr. Bourns, Hills of Rajampet, 1,200 ft., Cuddapah District, Noypauvelchady, Coimbatore ; Coll. Wight.
Wall. Cat.	6712 A.
W. India	Rajkot, Kathiawar, Bombay, Surat, Bombay ; October, 1910 ; Coll. P. S. Kanetkar, Gujarat, Bombay.
Central India	Guna, Isagarh District, Gwalior, September 1857.

22. Dicælospermum

Dicœlospermum C. B. Clarke in Hook. f. Fl. Brit. Ind. 2, p. 630.

A scabrid climbing slender herb. Tendrils simple. Leaves petiolate, ovate cordate or sub-hastate. Flowers white, minute, shortly pedicelled, monœcious, the male and the female in the same axils. Male flowers solitary or fascicled. Calyx-tube, short, campanulate; teeth 5, minute. Corolla deeply 5-partite; segments entire, triangular ovate, stamens 3, free, inserted on the calyx-tube; filaments very short; anthers oblong, one 1-celled, the others 2-celled; the cells straight, connective narrow, scarcely produced at the apex. Rudimentary ovary glanduliform. Female flowers unknown. Fruit dry, depressed globose, 1-celled. Seeds 3, erect, inserted at the bot om of the cell.

Distribution.—India (W. Peninsula), apparently endemic.

Dicœlospermum Ritchiei C. B. Clarke in Hook. f. Fl. Brit. Ind. v. 2, p. 630; Woodr. in Jour. Bomb. Nat. v. II (1898) p. 641.

Stems elongate, not much branched, grooved, scabrid. Tendrils slender, elongate, striate, sparingly hairy. Leaves $1\frac{3}{4}$-3 in. long and about as broad as long, deep green and sparingly hirsute above, paler hirsute and at length scabrid beneath, denticulate, usually ovate sub-triangular and slightly 3-lobed, the lateral lobes very short, acute, long, very scabrid (almost echinulate). *Male flowers* fascicled; peduncles filiform, $\frac{1}{10}$-$\frac{1}{5}$ in. long hairy. Calyx-tube $\frac{1}{10}$ in. long. *Female flowers* not seen. Fruit sessile, glabrous, smooth umblicate at the apex, about $\frac{1}{5}$ in. long and somewhat broader than long, red when ripe. Seeds whitish-brown, $\frac{1}{6}$ by $\frac{1}{5}$ by $\frac{1}{10}$ in., broadly ovoid, compressed, slightly beaked, longitudinally ridged and slightly rugulose in the middle, containing three cavities, the central enclosing the embryo, the 2 lateral empty.

Flowers July to September.

Habitat

Belgaum, also in Herb. Stocks, doubtless from Western India. District.—Apparently endemic. Stocks (without locality) in Herb. Kew; Konkan; W. Ghats near Matteran, Woodrow. Deccan S. M. country; Belgaum, Ritchie.

None of the specimens have female flowers, they have been collected in the fruiting condition.

Occurrence

W. India . . . . . Amboyne, 12 miles south of Lensli, Poona, October 1897; near Lansli, October 1897; Coll. G. M. Woodrow, Poona.

23. Cyclanthera

Cyclanthera, Schrad. Index Sem. Hort. Gotting, 1831, Linnæa, 8, Litt. p. 23 et Reliq. in Linnæa, 12, p. 408; Messn. Gen. Plant., p. 127 (92); Spach. Veg. phan. 6, p. 222; wndl. Gen. Plant n. 5143; Arn. in Hook. Journ. of Bot. 3, p. 280; Rœem. Syn. fasc. 2, p. 101; Naud. in Ann. sc. Nat. Ser. 4, v. 12, p. 158; Ser. 5, v. 6, p. 15; Benth. and Hook Gen. plant 1, p. 836; Cogn. Diagn. Cucurb. fasc. 2, p. 61 and in Mart. Fl. Bras. fasc. 78, p. 101.

Flowers monœcious. Male recemose or paniculate. Calyx tube pateriform or cupular, 5-dentate, subulate or filiform occasionally 0. Corolla rotate deeply 5-partite, segments broadly ovate oblong, often acute. Stamens united in a central column, filaments short; anthers top connate, loculus linear conduplicate or longitudinally dehiscent, or occasionally anthers horizontal annular unilocular circular dehiscent pollen ovoid, when dry, 4-5 furrowed globose when moist, apertures as many as the longitudinal furrows. Pistillode 0. Female flowers in the axil of the male flowers solitary. Calyx and corolla as in the male. Staminodes 0, ovary oblique, ovoid, rostrate, 1-3 locular or 2-many locular, occasionally trilocular, locules 2 septate with one ovule in each cell. Style stout stigma large, hemispherical. Ovules many when the ovary 1-2 celled and solitary when the ovary is multicellular, erect or oblique, ascending. Fruit oblique, ovoid gibbous and reniform, scarcely fleshy, prickly or spiny, rarely smooth. One to multilocular, 5 to many seeded, sprouting dehiscence, leaving a naked central or lateral placentiferous column. Seeds plain, angular, testa crustaceous smooth or rough, apex often bifid or bicuspidate.

A tropical or temperate American herb, scandent, glabrous or subglabrous, root annual or perennial. Leaves entire or lobed or pedate, 3-13 foliate. Tendrils simple or 2-many fid. Flowers often minute, yellowish green or white, sometime 6-merous.

Cyclanthera pedata Schrad. Index Sem. hort. Gothing. anno. 1831.

Stem glabrous; leaves pedate 5-7-foliate; leaflets sessile of subsessile, lanceolate or oblong-lanceolate, narrowed at base, apex acute or subobtuse and mucronate, denticulate or subcrenulate; tendrils 3-4-fid; male flowers small, in panicles semi-verticilate inflorescence, branches with many flowers; calyx denticulate with bristles, minute; fruit subsessile, sparcely spinous or smooth rostrate at the apex acute recurved.

Schrad. in Linnæa, 8, p. 23 and v. 12, p. 408; Spach. Veg. phan. 6, p. 223; Walp. Repert. 5, p. 761; Rœm. syn. fasc. 2, p. 101; Naud. in Ann. sc. Nat. Ser. 4, v. 12, p. 159; the Garden 12 (1877), p. 617 Cun. icone; Cogn. Diagn. Cucurb. fasc. p. 63.

Stem scandent, sufficiently robust, long, much branched, angular, smooth. Petiole robust, channeled, glabrous 5-15 cm. long. Leaves upper surface bright green; lower surface pale green, both sides punctate-scabrous more so on the upper surface; terminal leaflets 7-16 cm. long, 2-6 cm. broad; lateral ones somewhat small, outmost ones very deeply 2-3-lobed. Tendrils robust, elongate, channeled, glabrous. Common peduncles of the male flowers slender, angularly furrowed, glabrous smooth, 10-20 cm. long, 25-50 flowers; branches short, distant; pedicles filiform, spreading, fasciculate, subglabrous, tube 3-4 mm. long, teeth spreading, occasionally slightly flexuous, $\frac{1}{4}$-$\frac{3}{4}$ mm. long. Corolla golden yellow, segments broadly ovate triangular, acute 3-sub-5-nerved, both sides shortly sparingly pubescent glandular, $1\frac{1}{2}$-2 mm. long, 2-$2\frac{1}{2}$ mm. broad, apex papillose. Female peduncle 1-3 mm. long, calyx and corolla as in the male, somewhat larger. Ovary oblique oblong, narrowed at the apex and rostrate; style thick $\frac{1}{2}$-$\frac{3}{4}$ mm. long, stigma subloculate, 2 mm. broad. Fruit smooth gibbous, oblong, base narrow, occasionally sparingly echiniate. Green when young white when mature, bilocular 8-10 seeded, 5-7 cm. long, $2\frac{1}{2}$-3 cm. broad. Seeds subquadrate base truncate, apex appendicular, margin muricate. 10-12 mm. long, 7-8 mm. broad and 2 mm. thick.

Flowers about the end of October.

Habitat

N. W. Himalaya . . . Jeolikota, 4,000 ft., Kumaon, 22nd October 1912, Coll. N. Gill.

24. Actinostemma

Actinostemma Griff. Pl. Cantor., p. 24, tab. 3; Lindl. Veg. Kingd., p. 315; Endl. Gen. Plant Sullp. 5, p. 50; Griff. Notul. 4, 601; Naud. in Ann. Sc. Nat. Ser. 5, v. 5, p. 39; Benth. and Hook. Gen. Plant 1, p. 838; C. B. Clarke in Hook. f. Fl. Brit. Ind. 2, p. 632; *Mitrosicyos*, Maxim. Prin. Fl. Amus., p. 112 (1834) and in Ann. Sc. Nat. Sr. 4, v. 13, p. 95; *Pomasteriom* Miq. in Ann. Mus. hedg. Bat. 2, p. 80 (1865) and Prol. Fl. Jap., p. 12; Bull. Soc. bot. detr. 13, Revul., p. 8.

A slender climbing herb; tendrils simple, 2-fid. Leaves petioled, deeply cordate or hastate, elongate, much toothed, nearly glabrous. Flowers small, monoecious, in lax axillary panicles, pedicles jointed about their middle; panicles frequently male with a few females near the base. *Male:* calyx rotate 5-partite, with lanceolate linear segments; corolla 5-partite, segments lanceolate caudate; stamens 5, free; connective dilated-papillose on one side, with a narrow straight oblong anther-cell on the other. *Female:* calyx and corolla as in the male; ovary subglobose, verrucose, 1-celled; style short, with 2 reniform stigmas; ovules 2-4, pedulous, subparietal, capsule ovoid conical half superior, covered with rough points, circumscise above the middle. Seeds 2-4, compressed, ovate, corrugated and denticulate on the margin.

Species 4 of which only one is found in India.

Actinostema tenerum Griff. Pl. cantor 25; Clarke in Hook. f. Fl. Brit. Ind. p. 633 (exel syn.); *Sicyos oxycanthos* Wall. Cat. n. 6683; *Momordica Paina* Wall. Cat. n. 6742; *Mitrosicyos lobatus* Maxim. in Prin. Fl. Amur. 112, t. VII; *Pomasterion japonicum* Miq. Ann. Mus. Lugd. Bat. ii 80.

Leaves 4 by $2\frac{1}{2}$ in. acute, scarcely lobed in the Bengal specimens, palmately lobed in Maximowicz, petiole often 2 in. Panicles 2-6 in. fruit $\frac{3}{4}$ by $\frac{1}{2}$ in. not at all trigonas, upper part muricated as well as the lower. Seeds $\frac{1}{2}$ by $\frac{3}{8}$ in.

Habitat

Plain of E. Bengal, frequent Assam (Sylhet). Distrib. Amurland, Japan.

25. Zanonia

Zanonia Linn. Coroll., p. 19, Gen. ed. 2, p. 477, ed. 6, p. 523, Spec. ed. 1, p. 1028, ed. 2, p. 1457 (non Blum.); Reich. Gen., p. 519; Juss. Gen., p. 397; Neck Elem. 1, p. 1244; Schreb. Gen. 2, p. 690; Willd. Spec. 4, p. 769; A. St.-Hib. Mem. Mus. 9, p. 218; Bl. Bijdr., p. 937; Ser. in DC. Prodr. 3, p. 298; Poir. in Dict. Sc. Nat. 59, p. 254; W. and Arn. Prod. 1, p. 340; Meisn. Gen., p. 126 (91); Spach. Veg. Phan. 6, p. 189; Endl. Gen., p. 934; Arn. in Hook. Journ. of Bot. 3, p. 272; Rœm. Syn. fasc. 2, p. 113, 117; Miq. Fl. Ind. Bat. 1, Part 1, p. 682; Benth. & Hook. Gen. 1, p. 839; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 633.

Scandent glabrous or pubescent shrubs. Tendrils simple or bifid. Leaves petiolate, ovate or entirce. Flowers diœcious, all racemose or the males panicled. *Male flowers:* sepals 3, broadly oblong or orbicular, membranous concave. Corolla rotate 5-partite, coriaceous or fleshy; the segments narrowed at the apex. Stamens 5, free inserted on a fleshy disk; filaments very short and thick; anthers transversely oblong, adnate to the filaments 1-celled. Rudimentary ovary 0. *Female flowers:* calyx and corolla as in the male. Staminodes very short, alternate with the petals. Ovary, elongate at first 3-celled, at length 1-celled by the absorption of the septa; ovules 2-many in each cell, attached at both sides to pariental placentas, pendulous. Fruit cylindric, clavate or hemispheric terete or subtrigonous, truncate and broadly 3-valved at the apex. Seeds large pendulous oblong, compressed imbricate, surrounded by a large membranous wing. Distrib.—Tropical Asia, Java, Species 2.

Zanonia indica Linn. sp. Pl. ed. 2 (1763), p. 1457; Willd. Spec. 4, p. 769; Poir. in Lam. Encycl. meth. Bot. 8, p. 837, I. 11 des gen. 3, p. 407, tab. 816; Bl. Bijdr., p. 937; Ser. in DC. *Prodr.* 3, p. 298; Spach. Veg. phan. 6, p. 189; Rœm. Syn. Fasc. 2, p. 117; Wight & Arn. *Prodr.* 1, p. 340; Wight, I. 11. tab. 103; Miq. Fl. Ind. Bat. 1, part 1, p. 682; Thw. Enum., p. 124, 442; Clarke in Hook. f. Fl. Brit. Ind. 1, p. 633; Watt. Dict. Econ. Prod. v. 6, part 4, p. 322; Cogn. in Mongr. Phan. De. Candolle vol. iii, p. 926; Cook. Flora Presi. Bombay, Vol. I, p. 546.

Scandent, climbing to a height of 30-50 ft. Stems stout, cylindric, striate, woody, glabrous. Tendrils elongate, terete, glabrous. Leaves coriaceous, deciduous (leaving a permanent circular scar) 3-6 by 2-4 in. ovate-oblong, acute entire bright green and glabrous above, paler and conspicuously reticulate beneath, 3-nerved from a rounded or slightly cordate base; petiole $\frac{5}{8}$-$1\frac{1}{4}$ in. long, stout, glabrous. *Male flowers* in racemes or panicles 6-12 in. long; on slender grooved glabrous peduncles; pedicles somewhat stout, articulated about the middle, $\frac{1}{12}$-$\frac{1}{6}$ in. long, bracteolate at the base. Sepals $\frac{1}{12}$ in. long, ovate acute, concave glabrous. Petals greenish-yellow, oblong, obtuse $\frac{1}{6}$ in. long, $\frac{1}{12}$ in. broad at the base. *Female flowers* in 5-12 flowered recemes 4-12 in. long. Sepals broadly triangular, $\frac{1}{6}$ in. long. Petals ovate oblong $\frac{1}{4}$-$\frac{1}{3}$ in. long. Ovary cylindric, $\frac{1}{2}$ in. long. Capsule shaped like a candle extinguished 4-2 in. long, cylindric obconic, slightly tapering towards a rounded base, truncate at the apex, glabrous pale yellowish brown. Seeds much compressed, $\frac{3}{4}$ by $\frac{3}{8}$ in., pale yellow, smooth, the wing 2-$2\frac{1}{2}$ in. long by $\frac{1}{2}$ in. broad, rounded at the base and apex, fruit ripe in May.

Flowers January to October.

Habitat

Assam and East Bengal Griffith; Deccan Peninsula Wight; Malabar Mts. Stocks; Law, Dalzell; Ceylon not uncommon up to 2,000 ft. Thwaites. Distrib. Malaya.

Medicinal use

According to Rheede the leaves beaten up with butter milk, are used in South India as an anodyne application. The Sinhalese value the plant as a febrifuge (Thwaites*). The fruit is said to possess acrid cathartic properties. The Hakims in Bombay assert that the fresh juice is very

* Thwaites, G. H. K. (1859). *Enumeretio Plantarum Zeylanicum* 124

efficacious as an antidote to the venomous bites of the Gecko, known in the Deccan as Shal-i-alam or "king of the world" (S. Arjun*). In Malabar a bath made by boiling the leaves in water is used to remove the nervous irritation caused by boils, and an antispasmodic liniment is made by pounding the leaves with milk and butter.

Occurrence

Malaya Peninsula	Kinta Perak, 300 ft., January 1885; Coll. H. Kunstler, G. Borbo, 300-500 ft., March 1885; Dr. King's collector, banks of B. P. river, 300-400 ft., August 1885; Coll. Dr. King's collector.
Andamans	North Bay Hill Jungu, S. Andaman, 29th October 1892; Coll. Dr. King's collector.
Peninsular India	Tenmalai Travancore State, 11th September 1913; Coll. C. C. Calder and M. S. Ramaswami, Kalduntti, Travancore, 11th September 1913; Coll. Rama Rao, Travancore, Coll. M. A. Lowson, Tiagli, 2,000 ft., N. Kanara District, Bombay, 1896; Coll. W. Talbot.
Ceylon	Central Province.
Bengal	Royal Botanic Garden, Calcutta.
Assam	E. Bengal; Herb. Griffith.

26. Gomphogyne

Gomphogyne Griff. Pl. Cantor, p. 26, adnot. 4; Endl. Gen. Pl. Suppl. 5, p. 50; Benth. and Hook. Gen. Plant. 1, p. 838; C. B. Clarke in Hook. f. Fl. Brit. Ind. 2, p. 632; *Triceros* Griff. not pl. Asiat. 4, p. 606 (non Lour).—*Zanoniae* and *Alsomitrae* Spec. Auct.

Climbing weak, succulent herbs, tendrils 2-fid or simple. Leaves petioled, pedate, with 5-7 lanceolate, serrate leaflets. Flowers small, monoecious (sometimes at least), male racemed; females panicled or clustered. *Male:* calyx rotate, 5-partite, with oblong segments; corolla 5-partite with elongate lanceolate segments; stamens 5, filaments united at the base; anthers globose, 1-celled straight. *Female:* calyx produced above the ovary and the corolla as in the male; corolla segments caudate; ovary top-shaped, 1-celled; style 3, 2-fid. at the wide truncate summit, crowned by the persistent styles. Seeds 3 (2-1), ellipsoid, little compressed, black, obscurely margined. Distrib. Species 2, one in the Himalaya and the other in Burma.

Key to the species

Capsule succulent; seeds oblong	1. *G. Cissiformis.*
Capsule dry; seeds ovoid	2. *G. heterospermum.*

1. ***Gomphogyne cissiformis*** Griff. Pl. Cantor., p. 26, adnot., tab. 4; C. B. Clarke in Hook. f. Fl. Brit. Ind. 2, p. 632.

Leaves $2\frac{1}{2}$ in. diam., glabrous or slightly pubescent, apex acute or acuminate, base long attenuate, margin crenate dentate. *Male* racemes 1-6 in., simple or more often appearing compound towards the end of the leafless branches, provided with minute bractiolates. Calyx segments acute about $\frac{1}{10}$ in. long. Petals glabrous, trinerved margin obscurely denticulate $\frac{1}{6}$ in. long. *Female* clustered near the axils or on panicles 2-4 in. bracts subulate, elongate. Capsule somewhat succulent $\frac{1}{2}$ in. wide at the summit, seed $\frac{1}{4}$ in. oblong with scaly tubercles on the rounded faces.

Flowers about October.

Habitat

Garhwal alt. 750 ft., Madden; Kumaon 7,000 ft., Edgeworth, Strachy and Winter bottom; Sikkim 5,000-7,000 ft., Lachoong J. D. H.; Doobdi C. B. Clarke.

Var. glabra Cogn. Fruiting inflorescence slender, with long pedicle; fruit glabrous.

Var. villosa Cogn. Fruiting inflorescence stout, aggregated, with short pedicles; fruit tomentose. Sikkim in Lachoong cum var. (Hook. f. in herb Kew. Par. Vindob. Lugd.-Bat.).

*Arjun, S. (1879). *Catalogue of Bombay Drugs*, 260

Occurrence

N. W. Himalaya	Jumna valley between Rana and Banos in dampwoods, 8-9,000 ft., October 1899.
Sikkim	Doobdi, 6,000 ft., 10th October 1875 ; Coll. C. B. Clarke, Sikkim ; Coll. S. Kurz., Darjeeling, 7,000 ft., October 1880 ; Coll. G. S. Gamble, Sikkim, 5-7,000 ft. ; Coll. J. D. H., Dumsong, 6,000 ft., Darjeeling, December.
Java	S. Kurz.

2. ***Gomphogyne heterosperma*** Kurz. in Journ. As. Soc. Beng. 40, 1871 ; 11,58 Clarke in Hook. f. Fl. Brit. Ind. 2, p. 632 ; *Zanonia ? heterosperma* Wall. Listn. 3728 et Pl. Asiat. var. 2, 29 ; G. Don., Gen. Syst. 3, p. 4 ; Walp. Repert. 2, p. 194 ; Miq. Fl. Ind. Bat. 1, part 1, 683. *Alsomitra heterosperma* Rœm. Syn. fasc. 2, p. 118.

Leaves and inflorescence closely resemble *G. cissiformis*, capsule dry gribbed, $\frac{1}{2}$ in. narrow linear oblong, $\frac{1}{5}$ in. at the summit, seeds $\frac{1}{8}$ in. ovoid rugose-lacunose.

Habitat

Burma : Taong Dong. Wallich.

27. Gymnostemma

Gymnostemma Bl. Bijdr., p. 23 (1825) ; Linnæa. 1, p. 497 ; Spreng. Cur. post, p. 246 ; Meisn. Gen., p. 5 (7) ; Spach. Veg. phan. 8, p. 7 ; Endl. Gen. Pl. p. 827 ; Dcne. in Arch. du Mus. 1, p. 147, adnot ; Rœm. syn. fasc. 2, p. 21 ; Miq. Ind. Bat. 1, part 2, p. 687 ; Benth. and Hook. Gen. pl. 1, Fl. 839 ; C. B. Clarke in Hook. f. Fl. Brit. Ind. 2, p. 633 ; *Pestalozzia*, Zoll in Morr. Syst. verz. Zoll Plf., p. 31 ; Walp. Ann. 1, p. 316 ; Endl. Gen. Pl. suppl. 5, p. 50 ; *Enkylia* Griff. & Pl. Cantor., p. 26 ; Endl. Gen. Pl. suppl. 5, p. 50.

Climbing herb ; tendrils simple. Leaves pedate ; leaflets 3-5, ovate lanceolate, serrate, membranous. Flowers small, diœcious, in axillary diffuse panicles, greenish. Male calyx short, with 5 small lobes ; corolla rotate, 5-partite, with lanceolate segments ; stamens 5, filaments connate below ; anthers 2-celled ; cells long, straight. Female calyx and corolla as in the male ; ovary spherical 3-2-celled ; style 3-2 united at the base, at the apex 2-fid ; ovules in each cell 2, pendulous. Fruit globose, size of a pea, indehiscent, 1-3-seeded. Seeds not winged, verrucose, submuricate.

Key to the species

Leaflets (3-5) mostly glabrous beneath or slightly pubescent—3-5-foliate ; leaflets membranous	1. *G. pedata*.
Leaflets (3) densely pubescent, more so on the veins ; leaflets not membranous .	2. *G. barmanica*.

1. ***Gymnostemma pedata*** Blume. Bijd. ; Miq. Fl. Ind. Bat. i, pat. 687 ; *Enkylia digyna* and *trigyna*, Griff. Pl. Contor. 27 ; *Zanonia Wightiana* Arn. in Hook. Journ. Bot. ii, 272 ; *Z. cissoides* and *laxa*, Wall. Pl. As. Par. ii, 28, 29 ; Wall Cat. 3726, 3727 ; *Z. pedata*, Miq. Fl. Bat. i. pt. i. 683 ; *Pestalozzia pedata* Zoll. et Morr. Syst. Verz. 31 ; Enum 124. *G. cissiodes*, *pedata* and *Wightiana*, Bth. & Hook. f. Gen. Pl. i, 839.

Stem glabrous or pubescent. Leaflets mostly 5 or 3, $1\frac{1}{2}$-2 in. lanceolate or ovate lanceolate ; generally glabrous or slightly pubescent on both surfaces more or less membranous, ovate oblong or lanceolate ; margin umdulate or acuminate, leaf base attenuate ; petiole 1-$1\frac{1}{2}$ in., often pubescent with a line of crisped hairs. Panicles usually 3-6 in. sometimes 15 in. by nearly a foot broad, leafless ; bracteoles subulate $\frac{1}{20}$ in. long. Petals one-nerved, margin denticulate, when dry gives the appearance of a bird's claw, $\frac{1}{10}$-$\frac{1}{6}$ in. long. Style 2 and 3 on the same plant. Fruit $\frac{1}{6}$ in. diám., glabrous or puberulous. Seeds $\frac{1}{8}$ in. ellipsoid, subtrapezoid.

Habitat

Kumaon ; Strachey and Winterbottom. Nepal ; Wallich. Sikkim Assam, Khasia common upto 5,000 ft. ; Ceylon Thwaites ; Distrib. Malay and Japan.

2. ***Gymnostemma burmanica*** King. *ex* Chakravarti.

A rather stout climber. Stem pubescent more so on the tender parts. Leaflets 3, nerve 5, lanceolate or ovate lanceolate, densely pubescent with brownish coarse hairs on both surfaces more so on the under surface and aggreted closely on the veins. Middle leaflets 2-$2\frac{1}{2}$ in., side ones $1\frac{1}{2}$-$2\frac{1}{2}$ in. long, lanceolate or ovate lanceolate. Leaflets never nembranous rather thickish, margin umdulate or crenulate dentate, apex acute or acuminate, leaf-base attenuated; petiole 1-$1\frac{1}{2}$ in., generally densely pubescent. Panicles usually 3-6 in. or more. Flowers white; bracteoles $\frac{1}{20}$-$\frac{1}{10}$ in., calyx segments acute $\frac{1}{20}$ in. long. Petals one-nerved, membranous, denticulate, when dry, gives the appearance of a bird's claw, segments $\frac{1}{10}$-$\frac{1}{6}$ in. long. Fruit wanting.

The specimens have been collected from Burma. Dr. King named it *G. barmanica* King's Mss.

Occurrence

Burma . . . . . . Maymyo, Upper Burma, July 1888; Coll. J. C. Prazer, Southern Shan States, Taungyi, 1893; Coll. Abdul Khalil, Thamakhan, S. Shan States, Upper Burma; Coll. Abdul Khalil, Maymyo, July 1888; Coll. Badal Khan.

28. ALSOMITRA

Alsomitra Rœm. Syn. fasc. 2, p. 117, partin 1846 (non *Zanoniae* Sect. *Alsomitra* Bl. Bijdr., p. 937); Benth and Hook. Gen. 1, p. 840; Cogn. in Mart. Fl. Bras. fasc. 78, p. 113; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 634.

Large climbers; tendrils simple or 2-fid. Leaves with 3-oblong entire leaflets. Flowers small diœcious, white, in compound panicles, with filiform branches. *Male:* calyx rotate, 5-partite, segments oblong, acute; corolla rotate 5-partite, segments obtuse, stamens 5, filaments stout, near together at the base; anthers small oblong straight, 1-celled. *Female:* calyx and corolla as in the male; ovary elongate-clavate, 1-celled, sytle 3-4, conical, with semi-lunate stigmas; ovules very many, pendulous; placentas 3, thick, vertical, parietal.

Capsule large, elongate-clavate, truncate, and 3-valved at the apex. Seeds very many, compressed, vertical, in six rows, much corrugated, incised or horned on the margin with a terminal membranous wing, longer than the seed, or 0. Distrib. Species 10, extending from Nepal through Malay to North Australia.

KEY TO THE SPECIES

Leaves very fleshy; (fruit narrower) . . . . 1. *A. sarcophylla.*
Leaves herbaceous; fruit stout—
 Fruit glabrous . . . . 2. *A. clavigera.*
 Fruit tomentose . . . . 3. *A. pubigera.*

1. ***Alsomitra sarcophylla*** Rœm. Syn. fasc., p. 118; Kurz. in Journ. As. Soc. 1878, pt. ii, 106, Hook. f. in Bot. Mag. tab. 6017; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 634; *Zanonia sarcophylla* Wall. Cat. n. 3724; Pl. Asiat. var. 2, p. 28, tab. 133; Walp. Rep. 2, p. 194.

A lofty climber perfectly glabrous everywhere. Stem very slender, copiously branched; branches cylindric, pendulous. Leaves alternate, 3 foliate, petiole very short thick; leaflets 2-3 in. long elliptic-ovate or oblong, or ovate-lanceolate, obtuse or apiculate, quite entire, very fleshy, $\frac{1}{10}$ in., in thickness, bright green and obscurely 3-nerved above, channeled down the middle, paler and reticulated beneath; petiolules about as long as the petiole. Tendrils quite entire. Panicles slender axillary and terminal, pendulous, many-flowered, greenish yellow. Flowers diœcious, shortly pedicelled ebraceteate, $\frac{1}{3}$ in. in diameter, very pale strand-coloured. Sepals ovate-oblong acuminate, half as large as the rotate corolla; corol'a segments elliptic ovate and apiculate. Stamens small recurved, anthers smalladnate. Ovary club-shaped, 1-celled, many ovuled; ovules parietal; styles 3-4 short, conic, stigma semilunar, black. Fruit 2 inches long, subcylindric obtusely 3-gonous smooth, narrow at the base into the pedicel. Seeds compressed; nucellus obovate; testa black, muricate; wing oblong, obtuse hyaline.

A singular climbing evergreen plant, one of a small anomalous tribe of Cucurbitaceæ, which is distinguished by its fine stamens 1-celled anthers and ovary, and very curious fruit, which is almost cylindric, and opens by a tricural slit at the truncate top. It is a stove plant, and has remarkably

fleshy bright green foliage, which is admirably adopted for decorative purposes, keeping fresh for a very long time without water. The flowers which are individually insignificant, are produced in immense abundance. This plant is moreover valuable for being very free from the attacks of scale and other insects-pests of the hot house. It is a native of forests in Burma and Siam, abounding in arid, sterile and exposed situations along with the banks of the Irrawaddy river, where it was discovered by Dr. Wallich in 1826, flowering in the month of November.

Flowers November to February.

Habitat

Burma : from Mandalay to Prome, Wallich, Kurz ; Distributed to Siam.

Occurrence

Burma	Foulin Road, District Minbu, December 1902 Coll. Shaik Mokim ; Myimee, Sagaing District, 4th February 1904 Coll. Ramchandra ; Kyankse, common, Central Burma, 9th January 1904 ; Myaung-u-Minbu District, 19th March 1903 Coll. Aubert and Gage ; Minju, Upper Burma, 1893 Coll. Dr. King's collector ; Fort Stedman, Upper Burma, January 1893 Coll. Abdul Huk ; Collen, Upper Burma, January 1892 Coll. Abdul Huk ; Prome, Pegu, Coll. S. Kurz ; Shan States, Upper Burma, November 18, 1890 Coll. Abdul Huk ; Upper Burma November 1887 Coll. A. Collet ; Kumay Road, 2nd November 1892 Coll. Abdul Huk.
Wall. Cat.	3724, 18th November 1826, Prome Hills, 1826.
Siam	Radhburie, Kedah, September 1890 Coll. C. Curtis.

2. ***Alsomitra clavigera*** Rœm. Syn. fasc. 2, p. 118 ; Clarke in Hook. f. Fl. Brit. Ind. 2, p. 634 ; *Zanonia clavigera* Wall. Cat. n. 3725 ; Pl. As. rar. 2, p. 28 ; Walp. Rep. 2, p. 194 ; *Z. integerrima* Wall. Cat. n. 3725.

Stem slender, elongate, branches glabrous, sulcate ; petioles slender, $\frac{1}{2}$-$\frac{2}{3}$ in. long. Leaves herbaceous. Leaflets 3 by $1\frac{1}{2}$ in. acute petiolule often extending $\frac{1}{4}$ in. Fruit 3 by $\frac{3}{4}$ in. at the top, glabrous. Seeds including the wing 1 in. slightly muricated on the flat faces, yellowish-white, much flattened, with several deep triangular spinose teeth at the apex, teeth of 2 lamellæ, between which the wing is inserted, split in the plain of complanation of the fruit, and the wing springing from these narrow splits. Wallich's description of the seed of *Z. clavigera* is incorrect and appears to be taken from *Z. indica*, which grows in the same locality.

Flowers November to February.

Habitat

Sikkim, ascending to 4,000 ft., J. D. H., Gamble, C. B. Clarke. Khasia Mts., alt. 3,000-4,000 ft., H. f. & T. ; Sylhet. Wallich. Tenasserim ; Helfer (Kew Distrib. No. 2520).

Var. ? Hookeri : Seeds without any wing. Khasia Mts. alt. 3-4,800 ft.

Occurrence

Assam	Santong, 4,000 ft., 30th May 1895 Coll. Reporter on Economic Products to the Government of India ; Duphla Hills, Akha Hills, January 1890 Coll. Dr. King's collector ; Duphla Hills, January 1890 Coll. Badal Khan ; Gauhati, October 1850 ; Jerria Ghat, 1,000 ft., Khasi Hills, March 1891 Coll. H. Collett ; Kobo, Abor Expedition, 30th November 1911 Coll. I. H. Burkill.
Sikkim	Rungbee, 3,500 ft., Sikkim Himalaya, 18th February 1876 Coll. Dongboo.
Wall. Cat.	H. B. C. 2725 B, Sylhet 3725 A.
Malay Peninsula . . .	Kedah, 500 ft., 26th November 1921.

3. ***Alsomitra Pubigera*** Prain. Journ. As. Soc. Beng. Vol. LXXIII, part 2, p. 292-293.

Scandent shrub, branches beautifully elongate, branchlets puberulous sulcate. Leaves with short petioles pedate 5 leaflets ; leaflets with petiolules ; petiole scarcely straight $\frac{2}{5}$-$\frac{1}{2}$ in. long ; petiolule, terminal $\frac{3}{10}$ in. long, lateral ones $\frac{1}{10}$ in. long. Blade membranous, on both surfaces densely hairy, $1\frac{1}{2}$-4 in. long and $\frac{4}{5}$-$2\frac{1}{2}$ in. in breadth, ovate, acute, subobtuse or retuse margin wholly puberous ; base except the middle one partially oblique, membranous, the upper veins densely hairy

and the blade partially puberulous; panicles with many healthy flowers. Peduncle sulcate densely puberulous 2-4 in. long; pedicles puberulous $\frac{2}{5}$ in. long, bracteoles sulcate. The calyx puberulous segments lanceolate, linear acute, corolla glabrous, segments ovate, acute 1 in. long. The fruit subcylindrical with dense puberulous hairs from the top to the bottom, slightly attenuate, apex truncate, base subacute 2·25 in. long and $\frac{1}{2}$ in. in diameter, seeds subtriagular margin deeply lobed at the base, oblique attenuate $\frac{3}{10}$ in. long, ·25 in. in breadth and ·15 in. in diameter; winy white oblique translucent narrow oblong, apex round ·75 in. long, ·25 in. in diameter.

Flowers November to January.

This very distinct species is most nearly related to *A. clavigera*, the fruit except for being densely puberulous, being very like those of that species. But it differs very markedly in its pedate leaves and in its spinulose-rugose seeds.

Habitat

Burma . . . . . . Kachin Hills, Upper Burma, November 1897 Coll. Shaik Mokim; Kachin Hills, 300 ft., January 1898 Coll. Shaik Mokim.

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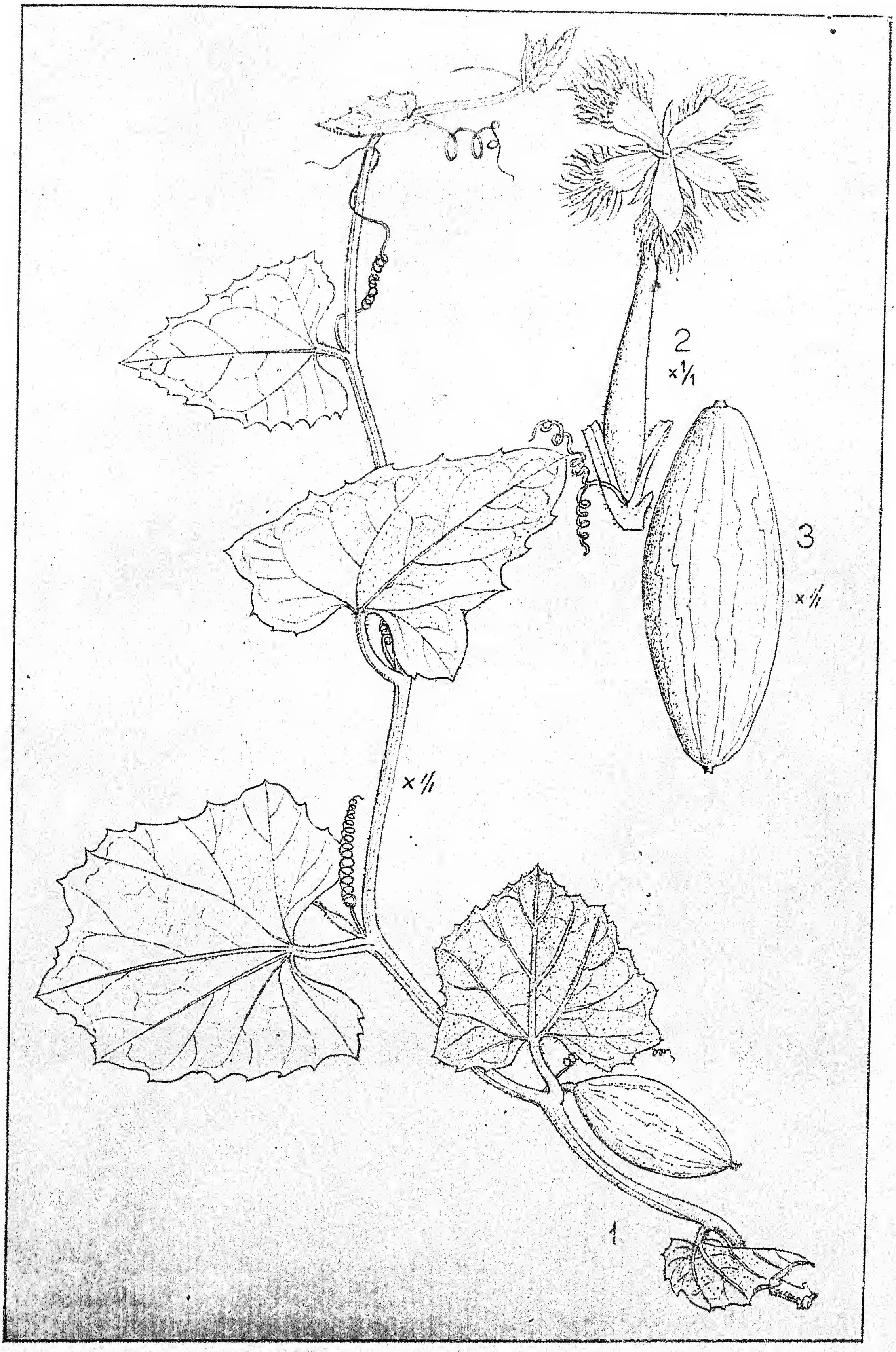
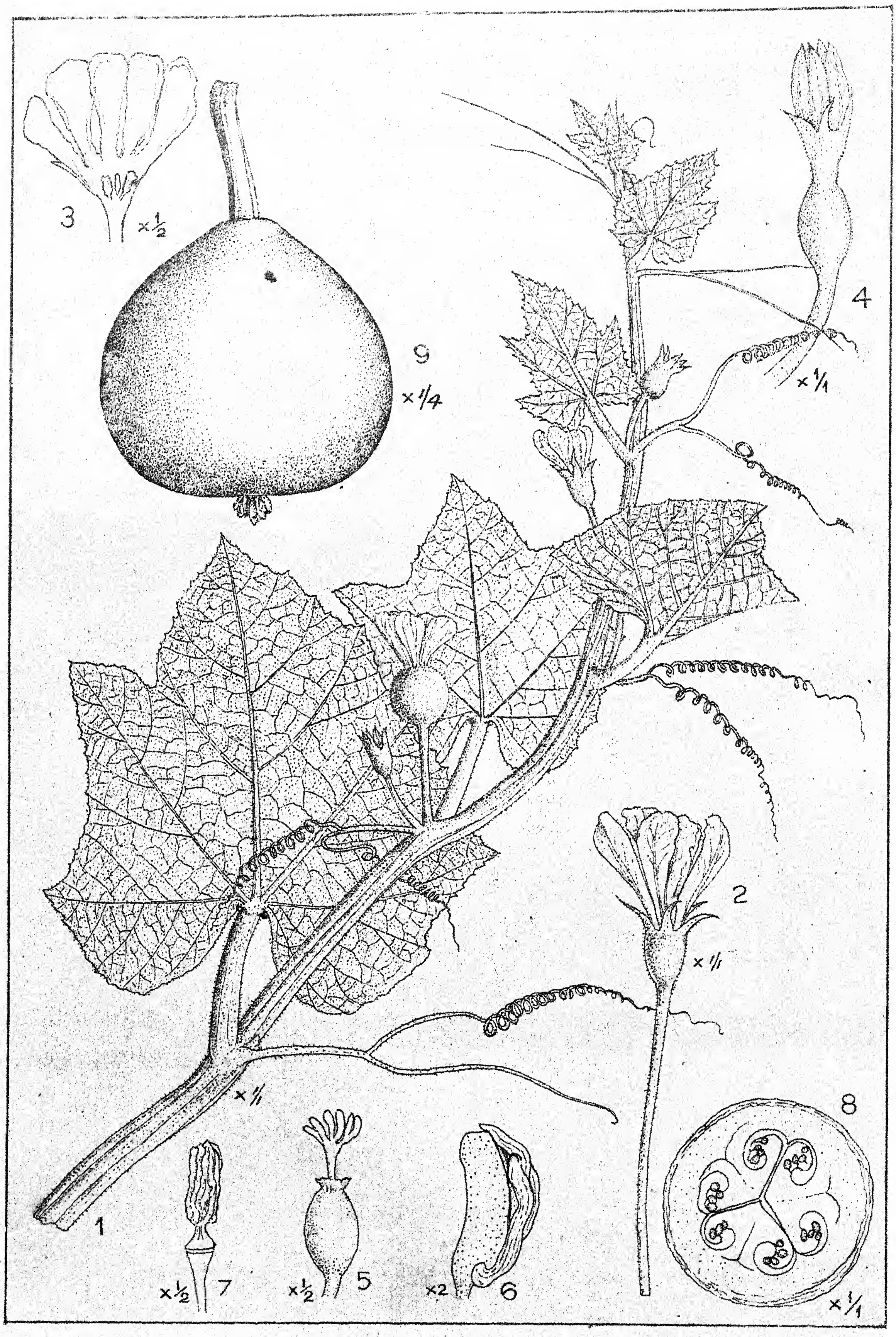


Trichosanthes dioica Roxb.



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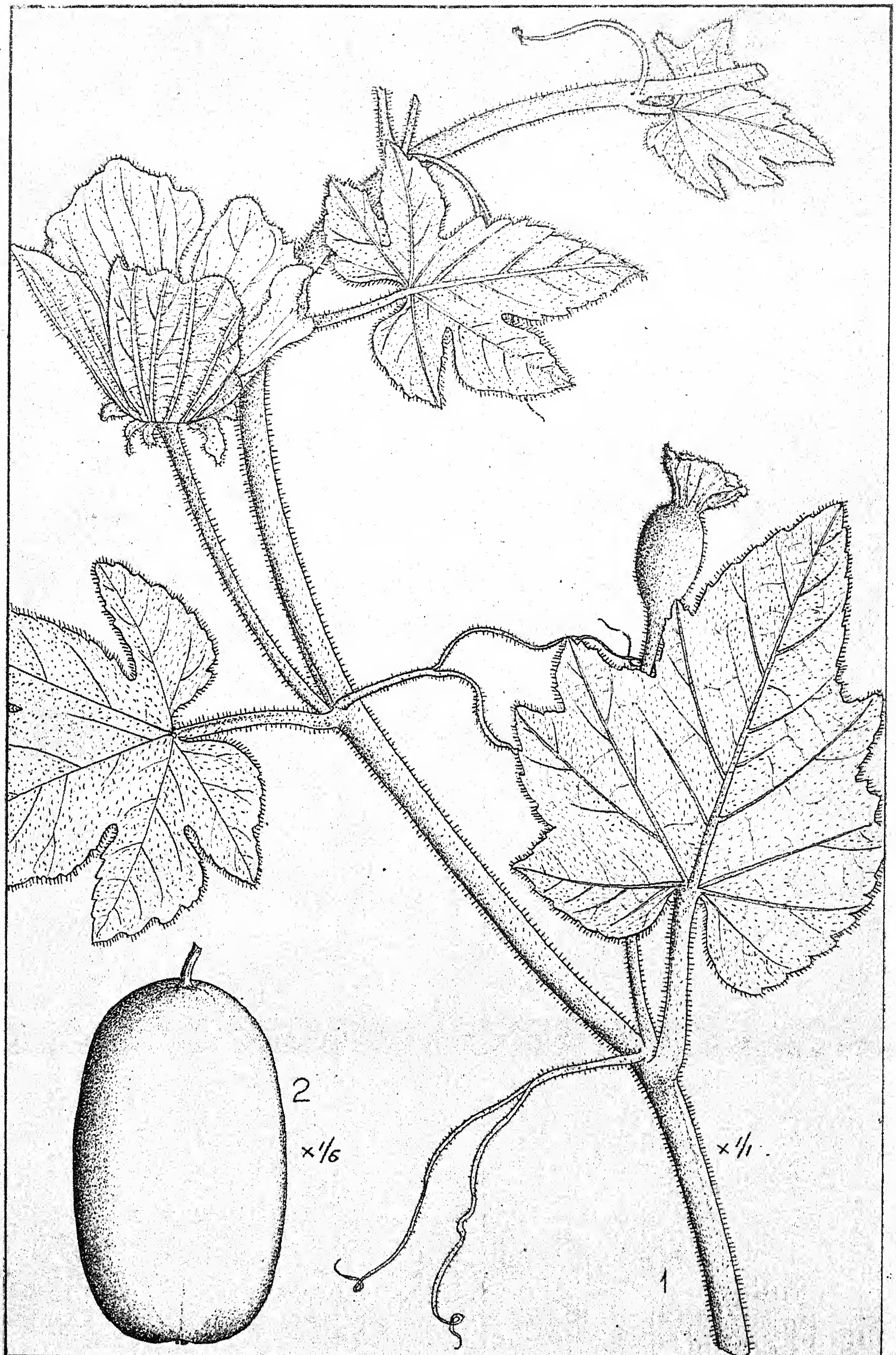
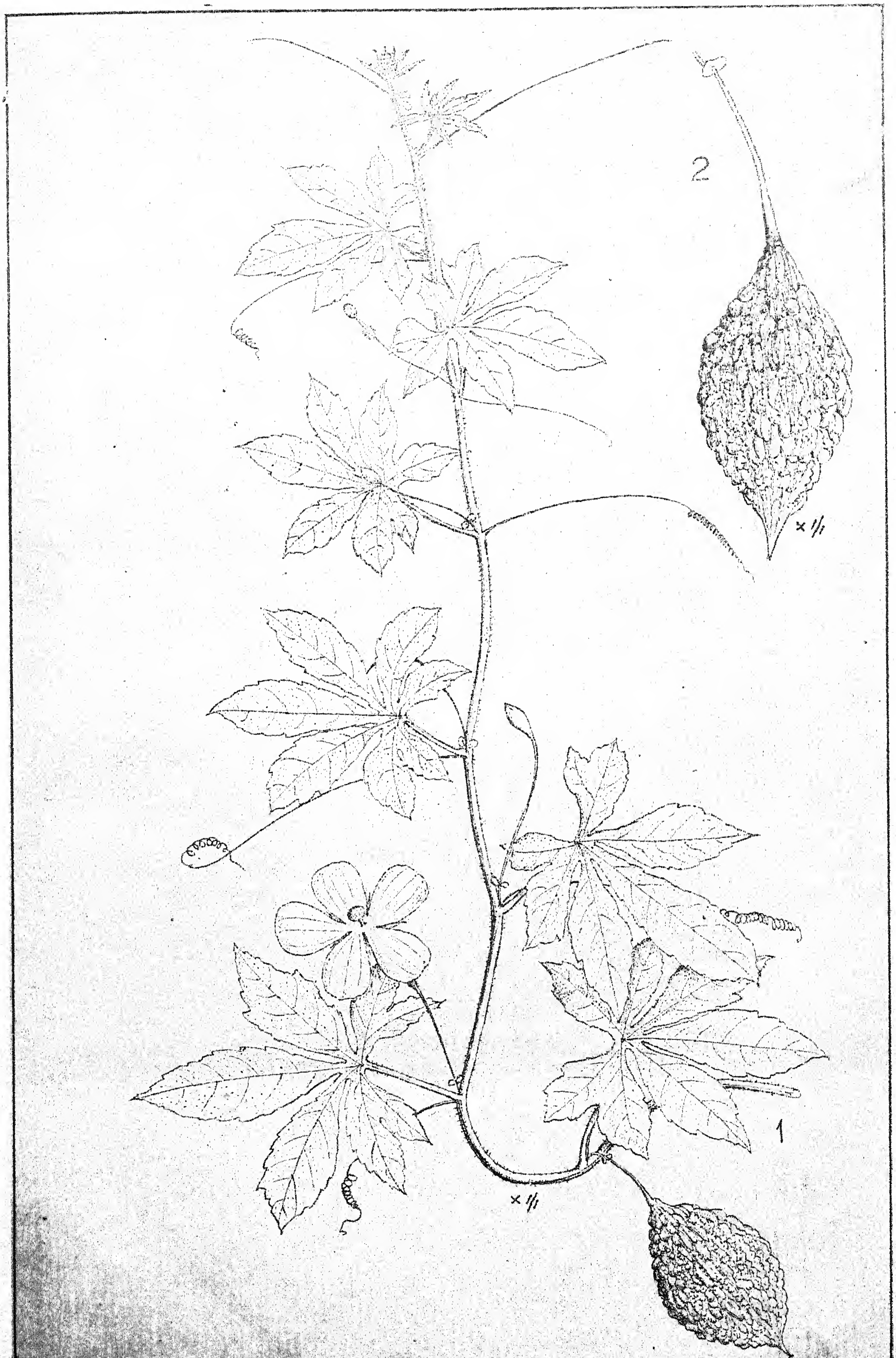


Benincasa hispida Cogn.

Momordica cochinchinensis Spreng.



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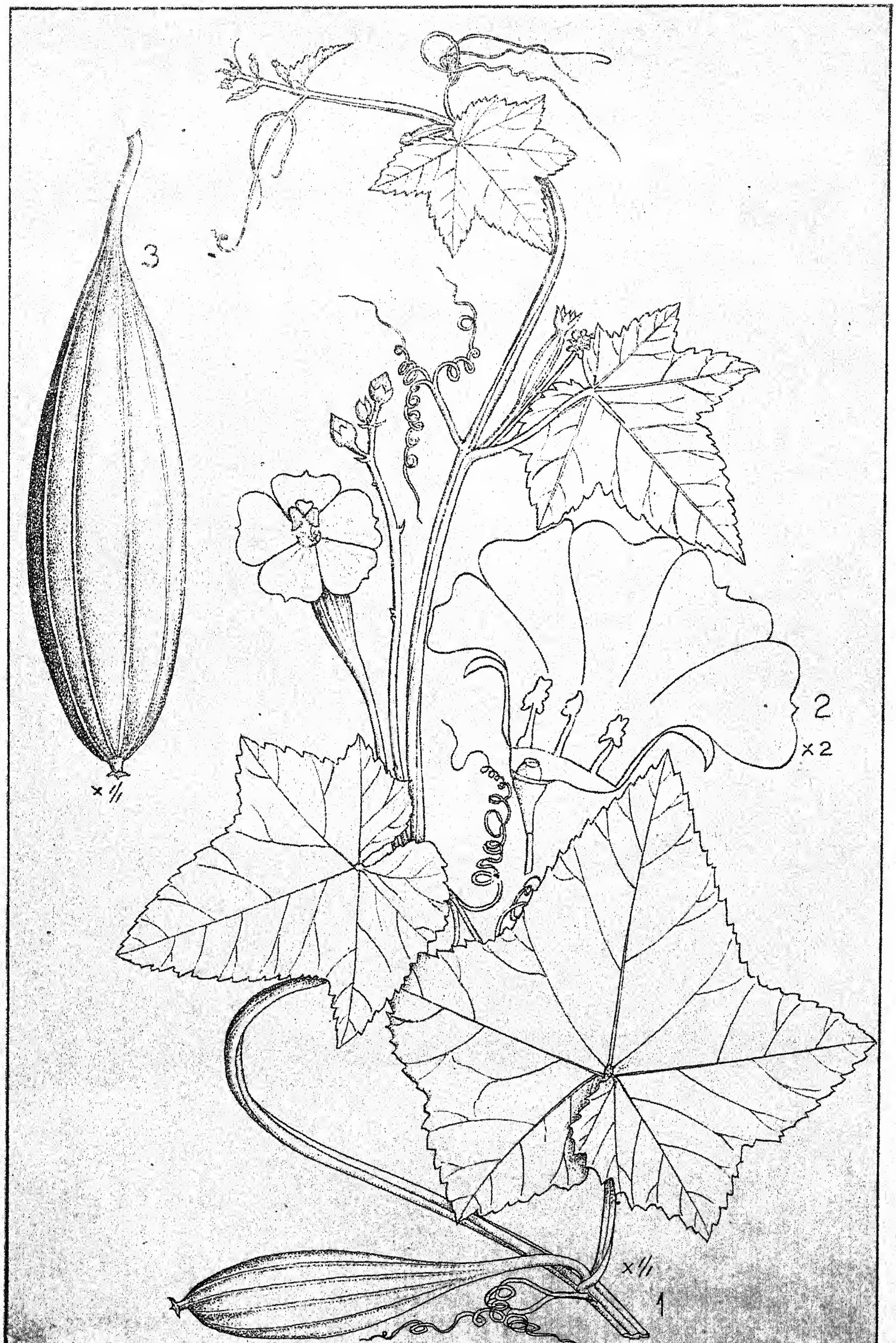
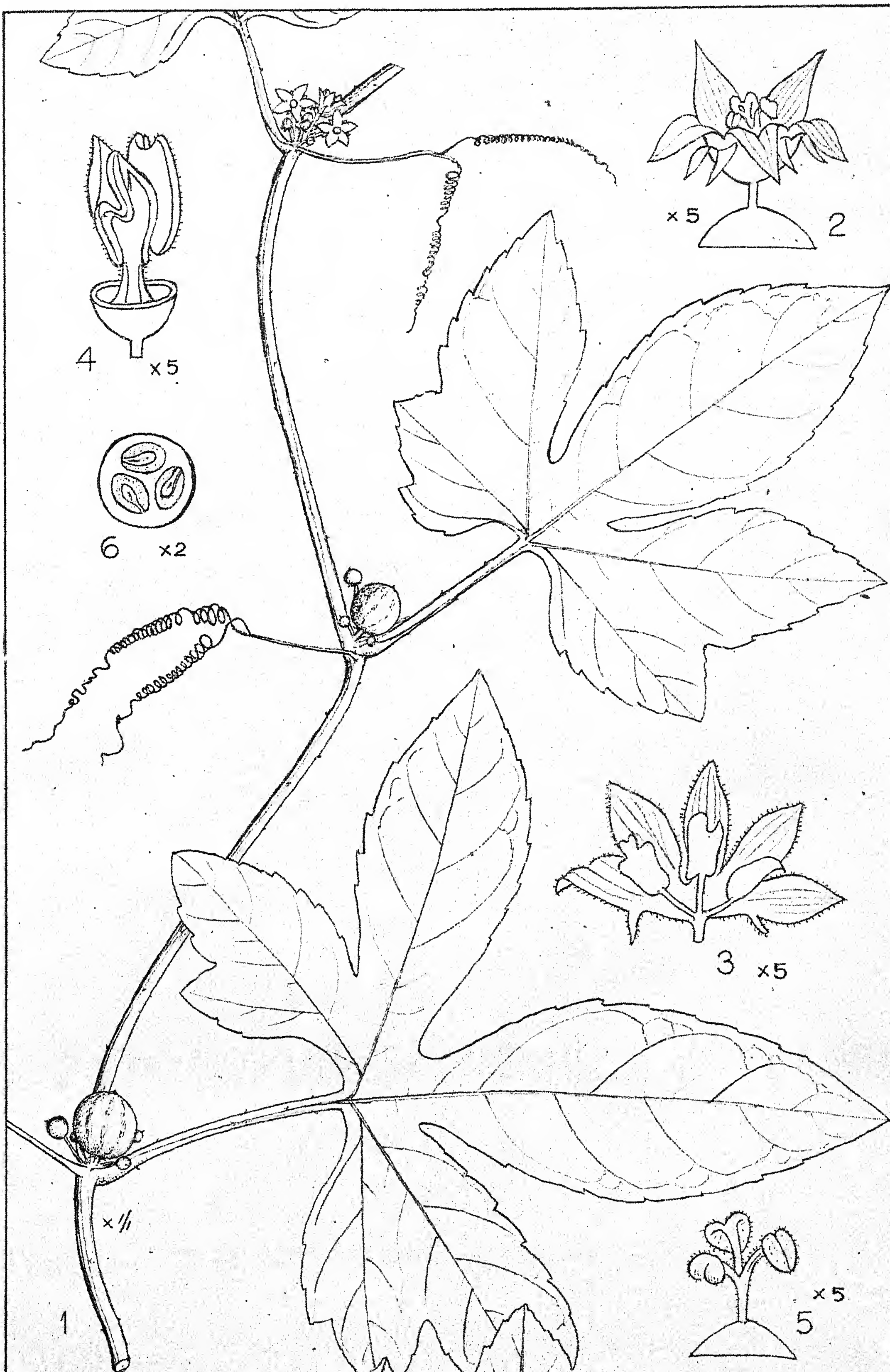
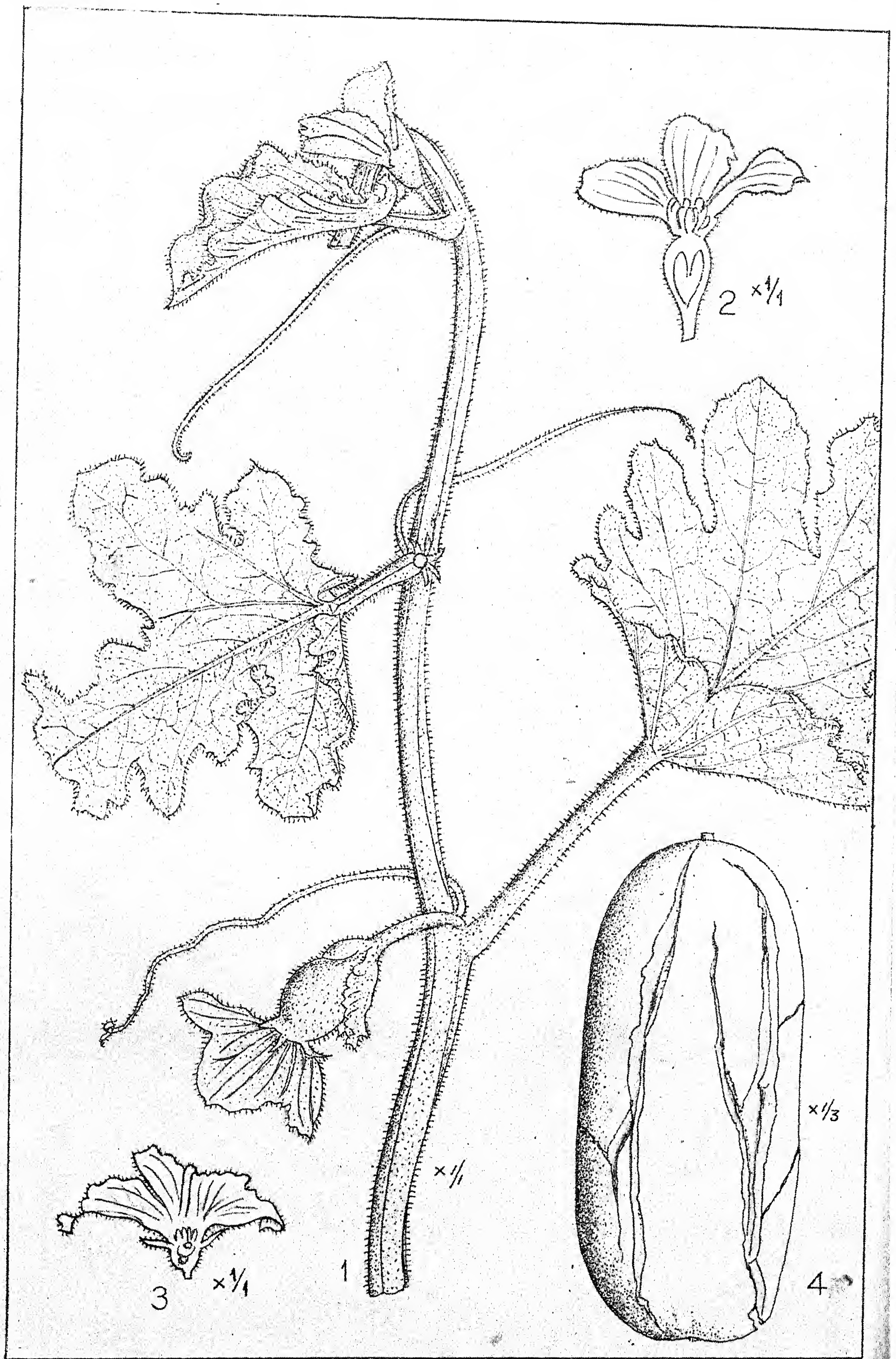


Luffa acutangula Roxb.



Bryonopsis laciniosa Naud.



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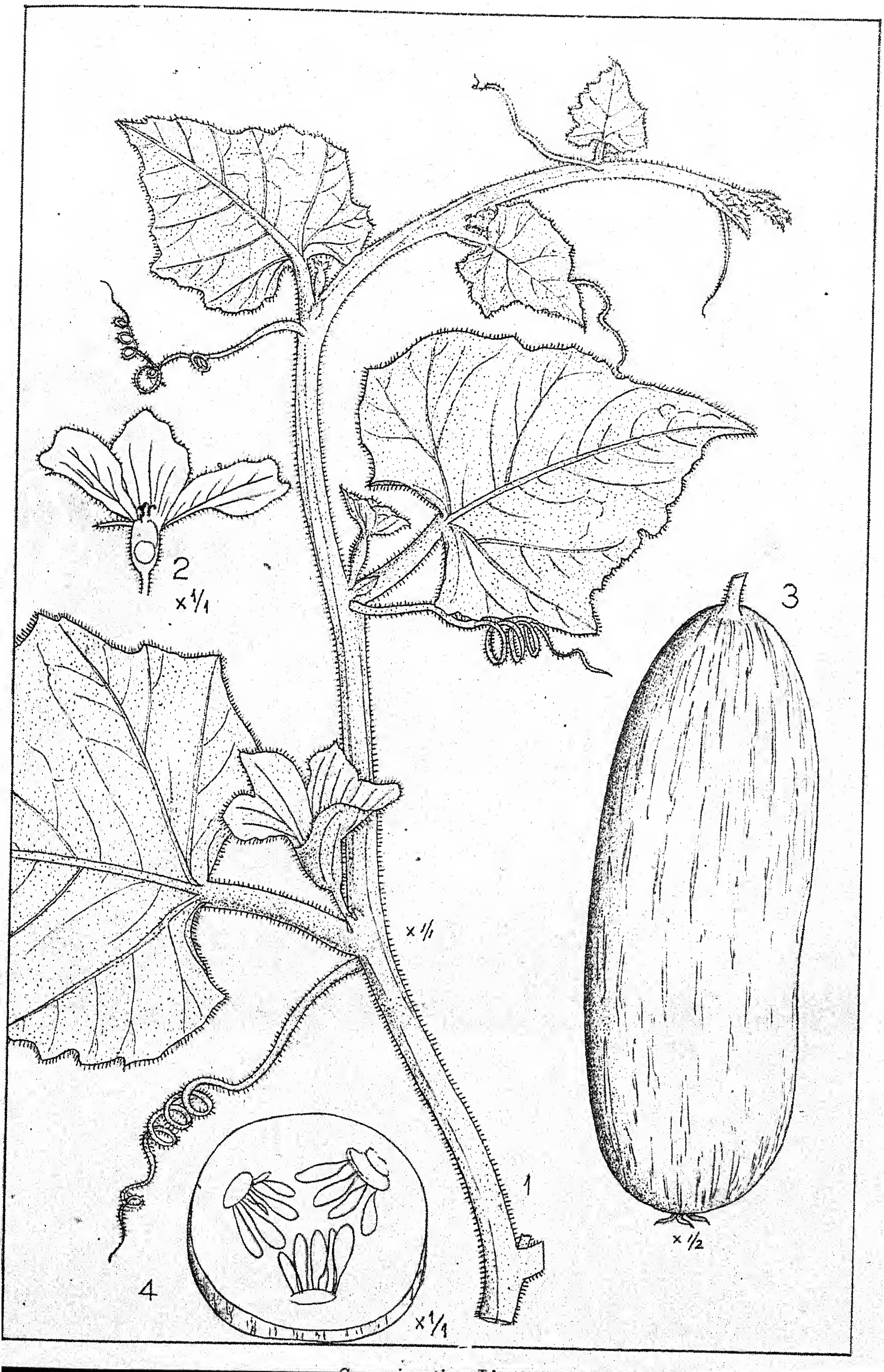
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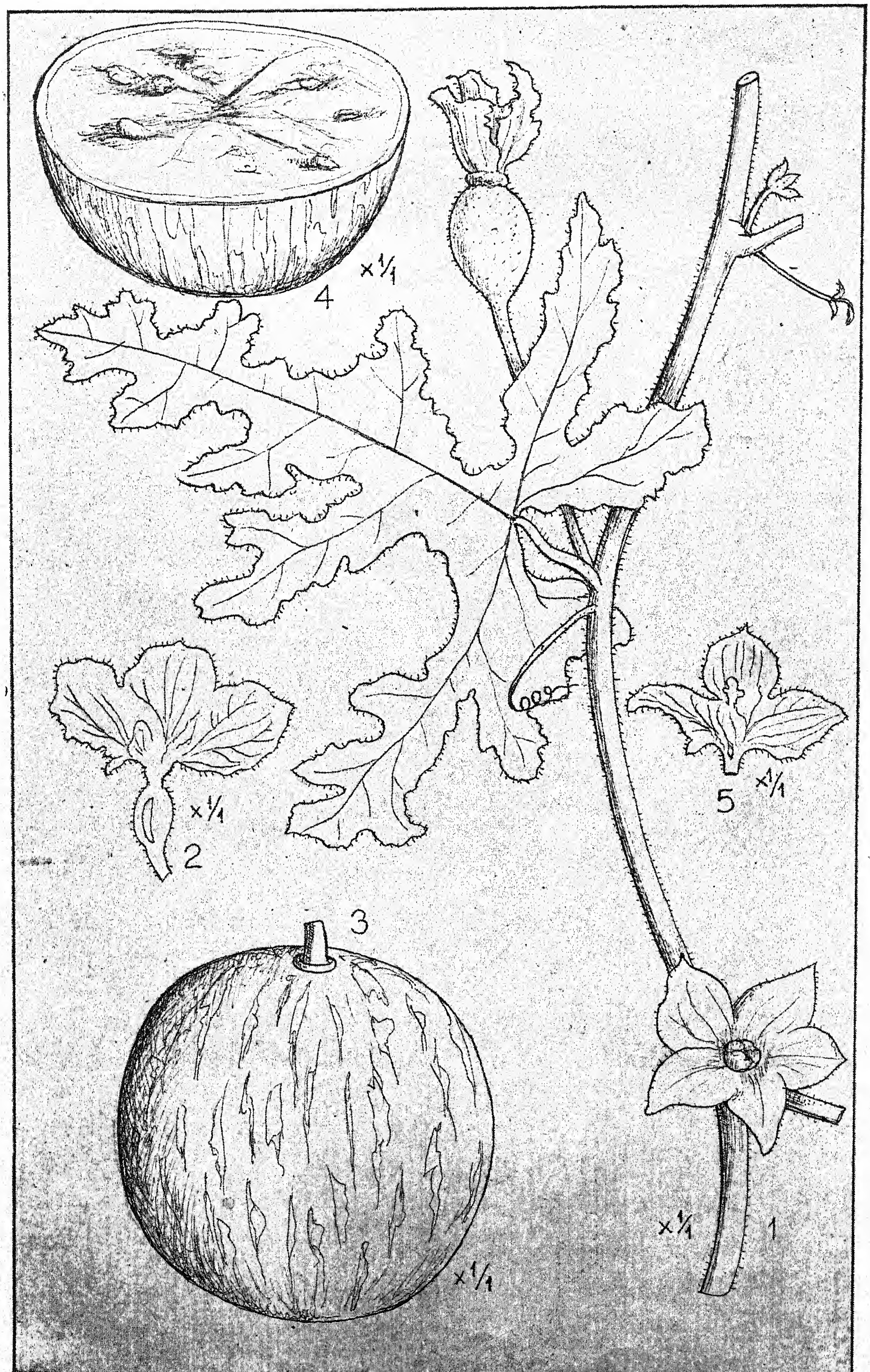
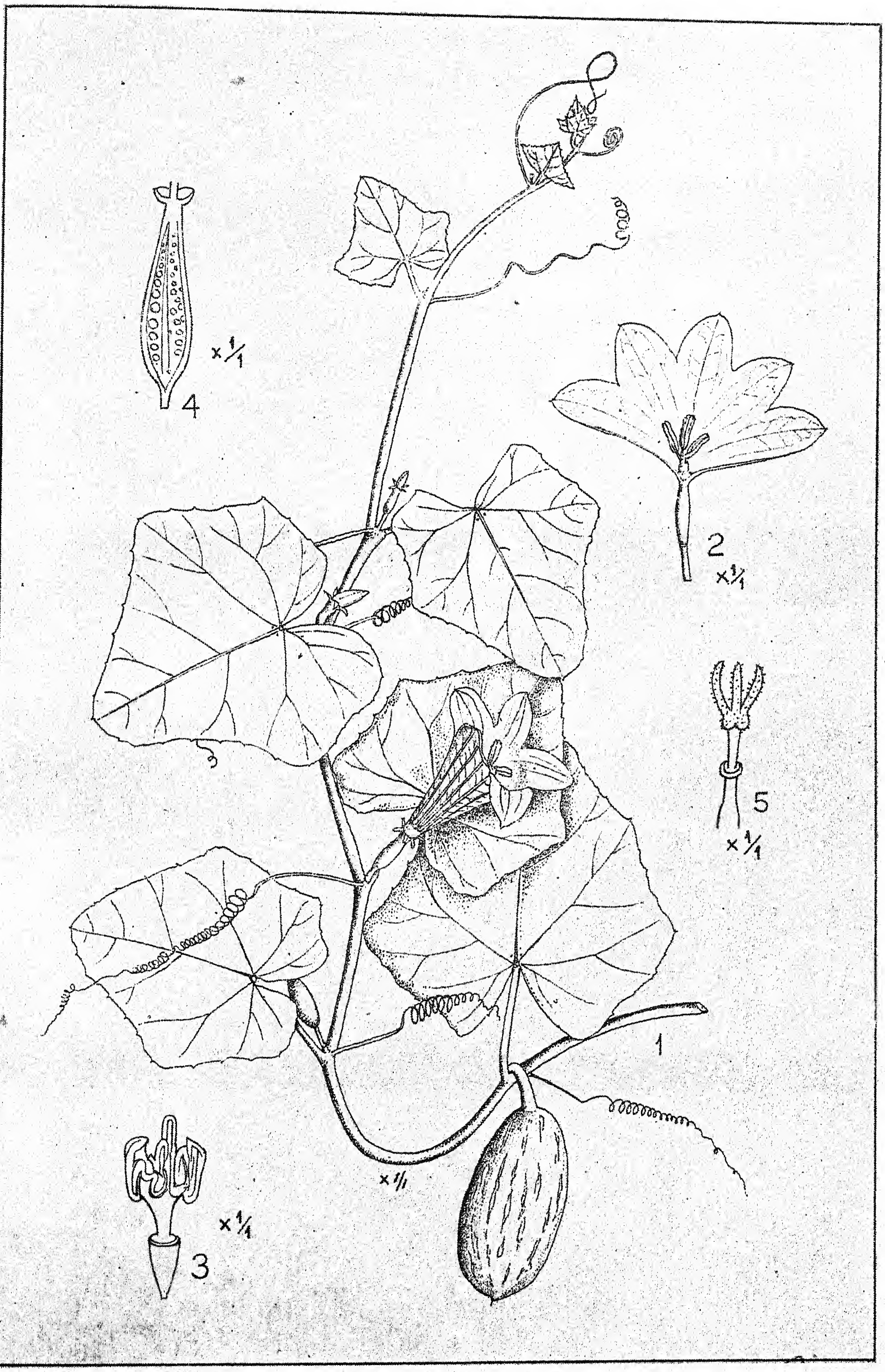
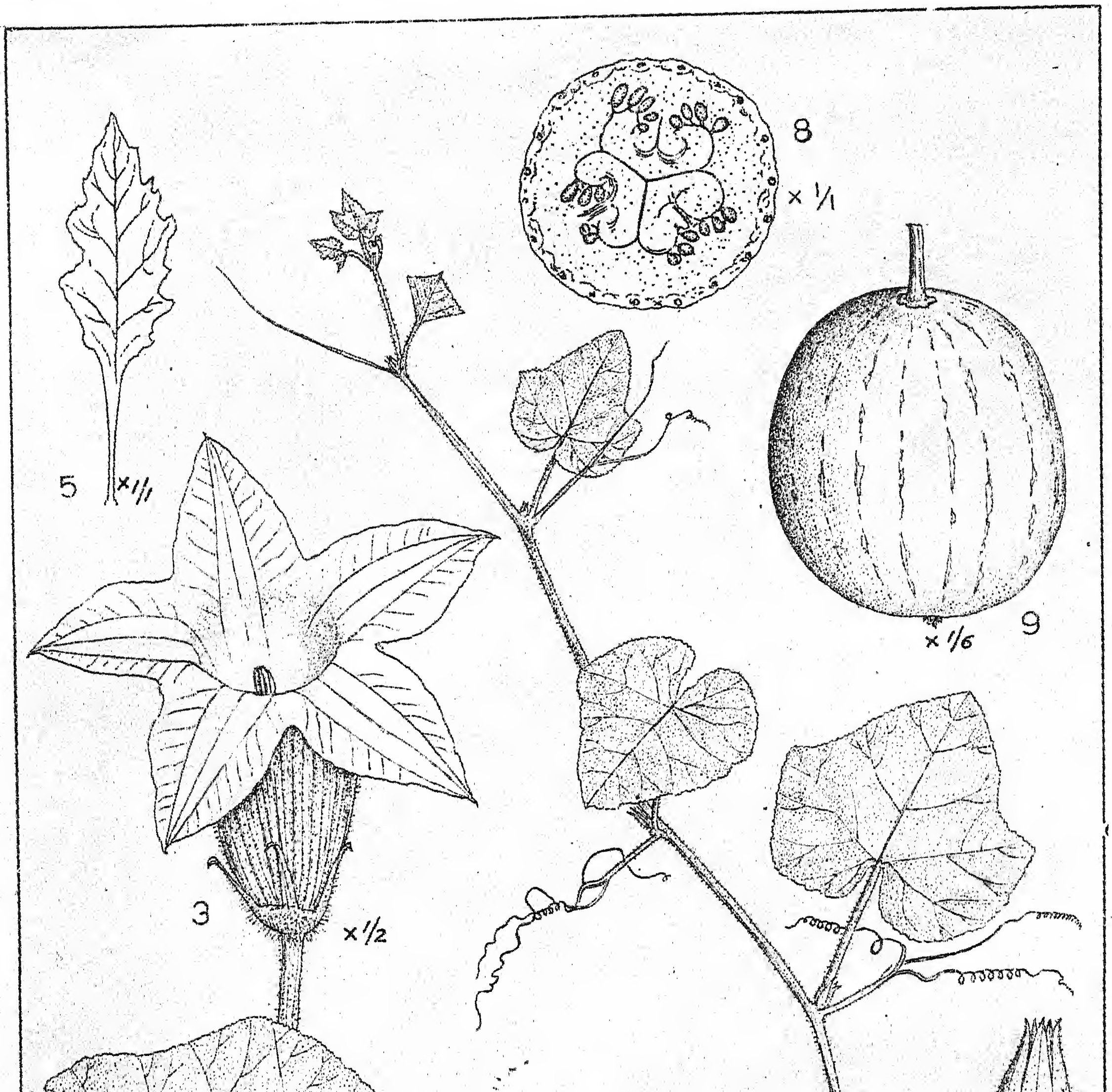




Coccinia indica Naud.



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EXPLANATION OF PLATES I—XII

PLATE I. *Trichosanthes dioica* Roxb. fig. 1 a fruiting branch × 1/1 ; fig. 2 a male flower × 1/1 ; fig. 3 a fruit. × 1/1.

PLATE II. *Lagenaria vulgaris* Ser. fig. 1 a flowering branch with female flowers × 1/1 ; fig. 2 a male flower × 1/1 ; fig. 3 dissection of a male flower × ½ ; fig. 4 a female flower × 1/1 ; fig. 5 a female flower calyx and corolla removed, showing ovary with style and stigma × 1/1 ; fig. 6 a stamen separated showing the nature and mode of attachment of the anther with the connective × 2 ; fig. 7 sinuated anthers × ½ ; fig. 8 section of ovary showing placentation × 1/1 ; fig. 9 a fruit × ¼.

PLATE III. *Benincasa hispida* Cogn. fig. 1 a flowering branch × 1/1 ; fig. 2 a fruit × 1/6.

PLATE IV. *Momordica cochinchinensis* Spreng. fig. 1 a flowering branch × 1/1 ; fig. 2 a fruit × ¼.

PLATE V. *Momordica charantia* Linn. fig. 1 a flowering branch × 1/1 ; fig. 2 a fruit × 1/1.

PLATE VI. *Luffa acutangula* Roxb. fig. 1 a flowering branch × 1/1 ; fig. 2 dissection of a male flower × 1/1 ; fig. 3 a fruit × 1/1.

PLATE VII. *Bryonopsis laciniosa* Naud. fig. 1 a flowering branch × 1/1 ; fig. 2 dissection of a female flower × 5 ; fig. 3 dissection of a male flower × 5 ; fig. 4 stamens and their attachment ×5 ; fig. 5 style and stigma × 5 ; fig.6 transverse section of ovary × 2.

PLATE VIII. *Cucumis Melo* Linn. fig. 1 a flowering branch × 1/1 ; fig. 2 a female flower × 1/1 ; fig. 3 a male flower × 1/1 ; fig. 4 a fruit × 1/3.

PLATE IX. *Cucumis sativus* Linn. fig. 1 a flowering branch × 1/1 ; fig. 2 dissection of a female flower × 1/1 ; fig. 3 a fruit × ½ ; fig. 4 transverse section of ovary × 1/1.

PLATE X. *Citrullus colocynthis* (Linn). Schrad. fig. 1 a flowering branch × 1/1 ; fig. 2 a female flower × 1/1 ; fig. 3 a fruit × 1/1 ; fig. 4 section of a fruit × 1/1.

PLATE XI. *Coccinia indica* Naud. fig. 1 a flowering branch × 1/1 ; fig. 2 dissection of a female flower with 3 staminodes × 1/1 ; fig. 3 stamens × 1/1 ; fig. 4 longitudinal section of ovary × 1/1 ; fig. 5 style and stigma.

PLATE XII. *Cucurbita maxima* Duchesne fig. 1 a flowering branch × ¼ ; fig. 2 a female flower × ½ ; fig. 3 a male flower × ½ ; fig. 4 a female flower calyx and corolla removed × ½ ; fig. 5 a foliaceous sepal × 1/1 ; fig. 6 stamens and their attachment with a glandular disc × ½ ; fig. 7 stamens × 1/1 ; fig. 8 transverse section of ovary showing placentation and glandular ovarian wall × 1/1 ; fig. 9 a fruit × 1/6.

DECOMPOSITION STUDIES WITH DIFFERENT TYPES OF COMPOSTS IN THE SOIL*

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DURING the course of pot-culture experiments with crops carried out in this laboratory, with a view to comparing the manurial behaviour of composts prepared by different methods, it was noticed that the degree of crop response was influenced not merely by the C/N ratio of the compost applied, but also by the nature of the waste material used in the preparation of the compost. Thus, for the same C/N ratio of the final manure, composts prepared from night-soil and town refuse were found to be more effective, per unit of nitrogen, than composts prepared from resistant farm wastes, e.g. sugarcane trash. As it was inferred that this difference in crop response must have been primarily due to the difference in the rate of liberation of available nitrogen in the two cases, it was considered advisable to carry out systematic experiments in the laboratory in order to compare the rates of

* Work carried out under the Scheme for the " Preparation of Compost Manure from Town Refuse and other Waste Material " financed by the Imperial Council of Agricultural Research

ammonification and nitrification of composts prepared under varying conditions and from different types of waste material.

The experiments were carried out by mixing weighed quantities of the manure with soil and incubating the mixture under optimum conditions of moisture and temperature for definite periods of time, after which the total carbon and nitrogen as well as ammoniacal and nitrate nitrogen present in the sample, were determined. Fuller details of the experimental procedure are given below.

Materials and methods

The soil used for the present experiments was a red loam obtained from the Experimental Farm attached to the Indian Institute of Science, Bangalore, which analysed as follows :

Table I

Analysis of soil used

Mechanical composition		Chemical composition	
	Per cent		Per cent
Coarse sand	33·4	Total carbon	0·59
Fine sand	26·4	,, nitrogen	0·058
Silt	7·7	,, P_2O_5	0·02
Clay	26·4	,, K_2O	0·22
Moisture	3·84	,, Lime (CaO)	0·10
Loss on ignition	3·19	Silica (SiO_2)	77·76
Carbonate	*nil*	Iron and alumina ($Fe_2O_3+Al_2O_3$)	13·75
*p*H	6·2		

It would be noted that the soil contains average amounts of carbon and nitrogen for Indian red loams, but is poor in phosphoric acid.

For the decomposition studies, weighed amounts of well-powdered, dry composts were added to 100 gm. portions of the soil in 250 c.c. wide-necked bottles, mixed thoroughly and incubated at 28°-30°C., after adjusting the moisture content to about 50 per cent of the water holding capacity, by the addition of distilled water. About 18 c.c. of water were required in the present case for each 100 gm. portion of soil. The loss of moisture during incubation was made up by fresh additions of distilled water every alternate day, and the mass was well stirred after each such addition, in order to ensure better distribution of moisture and aeration. Care was taken to add just enough water to bring the soil to a good tilth and to avoid clogging and anaerobic conditions due to excess of moisture. It was found that a visual check to ensure the above condition was more effective than weighing the bottles each time.

At the end of definite periods (2, 4, 8, 12 and 20 weeks) duplicate bottles were removed from the incubator and the whole of the contents were carefully scraped out and transferred into wide porcelain dishes to dry. The last traces of adhering soil and salts were washed out from the sides of the bottle with a small quantity of distilled water. The soil mass in the porcelain dish was dried in an incubator kept at 45°-50°C. and when dry was taken out and kept in the laboratory for a day in order that

equillibrium with the air might be achieved. The air-dry weight of the mass was determined, after which it was powdered and aliquots were taken for the determination of moisture, organic carbon, total nitrogen ammoniacal nitrogen and nitrate nitrogen. Organic carbon was determined by the chromic oxidation method of Acharya [1936], total nitrogen by the Gunning modification of Kjeldahl's method [A.O.A.C., 1935], ammoniacal nitrogen and nitrate nitrogen by Olsen's method [1929]. Changes in organic matter are expressed in terms of carbon and all values have been calculated in terms of the total quantities present in the experimental samples taken.

Decomposition of soil organic matter

Since in the present studies the decomposition of the organic matter present in the soil is likely to be superimposed on the decomposition of added compost material, a set of preliminary experiments was carried out in order to follow the course of decomposition of the organic matter originaally present in the soil and to test the influence of factors such as addition of lime or phosphate or diluting the soil with sand. Four sets of bottles were run—one set with soil alone without the addition of any chemicals ; the second set with soil mixed with 100 gm. of washed quartz sand ; the third set with soil mixed with 5 gm. of calcium carbonate ; and the fourth set with soil mixed with 100 gm. of sand and 0·5 gm. of potassium phosphate (K_2HPO_4). The other details relating to incubation and analysis were the same as given in the last paragraph and the results obtained are presented in Table II.

Table II

Carbon and nitrogen changes in incubated soil

Materials added	Incubation period	Total organic carbon in mg.	Total nitrogen in mg.	Ammoniacal nitrogen in mg.	Nitrate nitrogen in mg.	Total available nitrogen in mg.
I. 100 gm. soil without any addition of chemicals	Initial	590	58·0	*nil*	0·80	0·80
	2 weeks	606	61·2	0·52	1·20	1·72
	4 ,,	632	63·0	0·80	1·60	2·40
	8 ,,	624	64·2	1·20	2·40	3·60
	12 ,,	616	62·4	1·00	3·20	4·20
	20 ,,	598	60·2	0·80	2·60	3·40
II. 100 gm. soil +5 gm. calcium carbonate	Initial	590	58·0	*nil*	0·80	0·80
	2 weeks	608	62·2	0·32	1·20	1·52
	4 ,,	644	66·6	0·60	2·60	3·20
	8 ,,	626	61·4	0·80	3·80	4·60
	12 ,,	606	59·6	0·60	3·60	4·20
	20 ,,	586	57·2	0·30	1·80	2·10
III. 100 gm. soil +100 gm. sand	Initial	590	58·0	*nil*	0·80	0·80
	2 weeks	618	62·4	0·80	1·40	2·20
	4 ,,	636	64·8	1·40	2·80	4·20
	8 ,,	644	63·1	1·20	3·40	4·60
	12 ,,	612	60·8	1·00	3·80	4·80
	20 ,,	602	59·2	0·60	2·10	2·70
IV. 100 gm. soil +100 gm. sand +0·5 gm. K_2HPO_4	Initial	590	58·0	*nil*	0·80	0·80
	2 weeks	624	63·6	1·40	1·40	2·80
	4 ,,	652	68·4	1·80	2·80	4·60
	8 ,,	638	65·6	2·00	3·60	5·60
	12 ,,	622	63·4	1·60	4·20	5·80
	20 ,,	596	56·6	1·00	2·80	3·80

Carbon and nitrogen

On incubating the moist soil at 28°-30°C. there occurs in the first four weeks appreciable fixation of carbon and nitrogen from the atmosphere. The fixation is somewhat helped by the addition of lime or sand to the soil and is markedly improved by the addition of potassium phosphate. Under optimum conditions, the fixation of carbon amounts to about 10 per cent on the initial value and of nitrogen to about 18 per cent. The maximum values are generally reached at the end of four weeks. Similar data have been reported by Basu and Vanikar [1942].

The simultaneous fixation of carbon and nitrogen is explicable as being due to the rapid development of a nitrogen fixing algal flora in the soil [De, 1939 ; Allison and Hoover, 1935]. This algal flora is, in the second stage, probably attacked by bacteria, leading to the loss of both carbon and nitrogen.

The complication which this process of natural nitrogen and carbon fixation taking place in soils creates in interpreting data obtained on the decomposition of organic manures added to the soil, does not appear to have been emphasized by workers in the field. The degree of ambiguity caused in the present case is set out in Table III, wherefrom it would be seen that the quantities of carbon and nitrogen added to soil by natural fixation amount to about 40-60 per cent of the quantities normally added in the form of compost manure (at the rate of 10 tons of dry manure per acre which is equivalent to about 1 gm. of manure per 100 gm. of top soil).

TABLE III

Nitrogen and carbon in soil with and without manure

	Carbon in mg.	Nitrogen in mg.
I. Originally present in 100 gm. soil	590	58
II. Added in 1 gm. of dry compost per 100 gm. of soil representing 10 tons of dry manure per acre	120	10
III. Carbon and nitrogen fixed by 100 gm. of soil without manure in four to eight weeks (Table II)	40-60	6-8
IV. Available nitrogen (i.e. ammoniacal nitrogen + nitrate nitrogen) produced in the above soil in 8-12 weeks under optimum conditions (Table II)	..	4-6

While studying the carbon and nitrogen changes undergone by compost or other organic manure mixed with soil, one therefore meets with two different systems working simultaneously—one being the fixation processes taking place in the soil and the other being the decomposition processes occurring in the added manure. Since these react in opposite directions, the overall balance of total carbon and total nitrogen present in the system at any particular stage, would give no measure of the extent of decomposition undergone by the added manure. It is difficult to obtain values for the decomposition of the manure alone by deducting from the observed values the 'control' values for the incubated soil, since there is considerable interaction between the manure added and the fixation taking place in the soil; in other words, the carbon and nitrogen fixing capacity of the soil is markedly influenced by addition of organic manure.

Though the total carbon and nitrogen values of the soil-cum-organic manure system do not possess, from the scientific standpoint, any definite interpretative value, they possess considerable bearing on the 'practical' side, as indicating the 'overall' result that may be expected to occur in the field, when organic manures such as composts are applied to the land. From this point of view, it was considered worthwhile to include the total carbon and total nitrogen determinations in the experiments reported in this paper.

It would be noted from Table II that after the fourth week, both carbon and nitrogen values of the incubated soil show a progressive decrease and at the end of 20 weeks they recede back to the initial values.

The changes in ammoniacal and nitrate nitrogen of the incubated soil are of the usual recognized type. There is an accumulation of nitrate in the system for a period of 8 to 12 weeks, after which there is loss of nitrate, probably in the gaseous form. The total 'available' nitrogen, including in this term both ammoniacal and nitrate nitrogen, reaches a maximum at the end of 12 weeks, after which it shows a rapid fall. The quantity of 'available nitrogen' formed is slightly increased by the addition of lime or sand to the soil, and is markedly increased by the addition of potassium phosphate.

Preliminary trials with nitrogenous materials

Before undertaking studies relative to the decomposition of composts, it was considered advisable to test for the presence of an active microflora in the soil capable of bringing about rapid decomposition of added organic materials and nitrification of the ammonia produced. For this purpose, preliminary trials were carried out by adding to the soil various nitrogenous organic materials such as activated sludge, dried blood, egg albumin, hongay-cake, night soil and cattle dung, and carrying out incubation for 4 to 12 weeks. It is unnecessary to present the data so obtained, but they showed the presence of an active microflora in the soil, which brought about carbon decomposition, ammonification and nitrification.

Decomposition of composts

A large number of samples of composts prepared by different methods in connection with the work reported elsewhere [Acharya, 1939 and 1940] were used in the present decomposition studies, but in order to avoid repetition of data obtained for similar types of composts, only such data are presented as have a direct bearing on the three important factors referred to at the head of this paper as possibly influencing the rate of nitrification of composts, viz. (*a*) nature of waste material used, (*b*) C/N ratio of the compost, and (*c*) method of preparation.

In order to obtain a wide range of necessary samples, three methods of composting were tried, viz. (*a*) aerobic method, with turnings every fortnight for three months; (*b*) hot fermentation method in trenches [Acharya, 1939 and 1940]; and (*c*) plastering the compost mass in trenches with mud paste from the beginning, without any subsequent turning, which for convenience of denomination could be styled 'anaerobic'. Method (*a*) gave products of the narrowest C/N ratios and (*c*) the widest. By applying these three methods to different types of refuse, e.g. (i) night-soil and town refuse, (ii) farm refuse containing cattle dung and urine, and (iii) farm refuse poor in nitrogen, e.g. sugarcane trash, it was possible to obtain a series of composts, prepared from different types of waste material, possessing C/N ratios varying from 10 : 1 to 30 : 1. Fuller particulars of the composts so prepared are given in Table IV.

Table IV

Nature of composts used in the decomposition studies

List No.	Nature of original refuse	Method of composting	Analysis on dry basis: Carbon per cent	Nitrogen per cent	C/N ratio
A	Compost from town refuse and night soil	Aerobic, in heaps overground	11·45	1·08	10·6
B	Do.	Hot fermentation in trenches	15·62	1·26	12·4
C	Do.	Anaerobic, in trenches	18·81	1·14	16·5
D	Compost from mixed farm refuse (leaves, weeds, dung, urine, etc.)	Aerobic, in heaps overground	9·27	0·82	11·3
E	Do.	Hot fermentation in trenches	13·63	0·96	14·2
	Do.	Anaerobic, in trenches	17·17	0·81	21·2
G	Compost from sugarcane trash	Aerobic, in heaps overground	9·83	0·64	13·8
H	Do.	Hot fermentation in trenches	11·80	0·69	17·1
I	Do.	Anaerobic, in trenches	17·70	0·53	33·4

Enough of the manure was added in each case to supply 20 mg. of nitrogen per 100 gm. of soil. The results obtained are set out in Table V.

TABLE V

Carbon and nitrogen changes during the decomposition of composts in the soil

Manure No.	Nature of compost	C/N ratio	Period of incubation	Total carbon in mg.	Total nitrogen in mg.	Ammonia-cal nitrogen in mg.	Nitrate nitrogen in mg.	Total available nitrogen in mg.
A	Town refuse + night soil, compost, aerobic	10·6	Initial	802	78·0	*nil*	0·80	0·80
			2 weeks	761	75·2	2·24	1·20	3·24
			4 ,,	744	73·1	2·02	4·46	6·48
			8 ,,	752	76·0	1·40	9·14	10·54
			12 ,,	786	78·4	1·20	7·20	8·40
			20 ,,	772	76·2	0·80	5·26	6·06
B	Town refuse + night soil, hot fermentation	12·4	Initial	838	78·0	*nil*	0·80	0·80
			2 weeks	799	76·2	1·80	1·04	2·84
			4 ,,	766	74·8	2·42	2·76	5·18
			8 ,,	764	77·6	2·02	7·64	9·66
			12 ,,	786	80·2	1·44	8·74	10·18
			20 ,,	798	82·6	1·02	7·58	8·60
C	Town refuse + night soil, anaerobic	16·5	Initial	920	78·0	*nil*	0·80	0·80
			2 weeks	896	77·3	1·24	*nil*	1·24
			4 ,,	862	76·7	2·04	2·22	4·26
			8 ,,	841	78·4	1·84	5·78	7·62
			12 ,,	822	81·6	1·26	7·56	8·82
			20 ,,	808	83·4	0·96	7·22	8·18
D	Mixed farm refuse, compost, aerobic	11·3	Initial	816	78·0	*nil*	0·80	0·80
			2 weeks	791	76·6	1·86	1·24	3·10
			4 ,,	774	74·2	2·04	3·62	5·68
			8 ,,	766	78·4	1·80	6·96	8·76
			12 ,,	782	79·2	1·42	7·22	8·64
			20 ,,	794	80·5	0·94	6·46	7·60
E	Mixed farm refuse, hot fermentation	14·2	Initial	874	78·0	*nil*	0·80	0·80
			2 weeks	841	77·2	1·46	*nil*	1·46
			4 ,,	819	75·4	1·84	2·56	4·40
			8 ,,	801	79·2	1·46	5·86	7·32
			12 ,,	796	81·8	1·64	6·24	7·88
			20 ,,	811	83·6	1·22	5·02	6·24
F	Mixed farm refuse, anaerobic	21·2	Initial	1014	78·0	*nil*	0·80	0·80
			2 weeks	972	78·6	*nil*	*nil*	*nil*
			4 ,,	933	80·1	0·82	0·26	1·08
			8 ,,	899	81·3	1·24	1·92	3·16
			12 ,,	868	82·6	1·46	3·22	4·68
			20 ,,	831	84·2	1·02	4·68	5·70
G	Sugarcane trash compost, aerobic	13·8	Initial	866	78·0	*nil*	0·80	0·80
			2 weeks	834	76·2	1·24	*nil*	1·24
			4 ,,	809	75·6	1·68	1·34	3·02
			8 ,,	798	77·4	1·84	3·66	5·50
			12 ,,	789	78·6	1·64	4·88	6·52
			20 ,,	798	80·8	1·24	5·24	6·48

TABLE V—*contd.*

Carbon and nitrogen changes during the decomposition of composts in the soil—contd.

Manure No.	Nature of compost	C/N ratio	Period of incubation	Total carbon in mg.	Total nitrogen in mg.	Ammoniacal nitrogen in mg.	Nitrate nitrogen in mg.	Total available nitrogen in mg.
H	Sugarcane trash compost, hot fermentation	17·1	Initial	932	78·0	*nil*	0·80	0·80
			2 weeks	901	77·2	*nil*	*nil*	*nil*
			4 ,,	873	78·2	1·24	0·68	1·92
			8 ,,	848	79·6	1·64	1·88	3·52
			12 ,,	829	81·4	1·82	3·42	5·24
			20 ,,	819	83·0	1·24	3·84	5·08
I	Sugarcane trash compost, anaerobic	33·4	Initial	1258	78·0	*nil*	0·80	0·80
			2 weeks	1162	78·2	*nil*	*nil*	*nil*
			4 ,,	1074	78·8	*nil*	*nil*	*nil*
			8 ,,	998	80·2	0·86	*nil*	0·86
			12 ,,	938	82·4	1·64	0·80	2·44
			20 ,,	882	84·6	1·84	1·48	3·32

Changes in total carbon

The figures presented in Table V show that though the initial quantities of carbon present in the soil-cum-compost systems A to I varied greatly from 800 to 1260 mg., there was a tendency for the carbon figures to come down rapidly to a stable level round about 780-800 mg., this level of 780-800 mg. carbon corresponds to a C/N ratio of about 10 : 1 and is in agreement with the known comparative stability of soil humus which exhibits a similar C/N ratio.

Changes in total nitrogen

There is a decrease in total nitrogen in the first few weeks of decomposition, especially in cases where the initial C/N ratio of the manure is narrower than 15 : 1, after which there is a period of progressive increase in total nitrogen, due presumably to fixation from the air. The fixation is inappreciable in cases where the C/N ratio of the compost is near 10 : 1, but it increases markedly as the ratio gets wider. Thus, in the case of composts F and I (Table V), whose C/N ratios are wider than 20 : 1, the final nitrogen content of the soil-cum-compost system at the end of 20 weeks is about 8 per cent higher than at the start.

A comparison of the data presented in Table V against that presented in Table II would show that the addition of compost of C/N ratio narrower than 15 : 1 delays the start of the natural nitrogen fixation processes occurring in the soil by about 4 to 8 weeks. After the above interval, fixation of both carbon and nitrogen from the air start taking place progressively. In cases where composts with C/N ratios wider than 15 : 1 are added, the above lag period in nitrogen fixation is considerably lessened, but even in such cases, the overall fixation of nitrogen (2 to 4 mg.) is less than in the case of soil alone (6 to 8 mg. Table II). The lower fixation in presence of added compost may be due to the fact that the nitrogen level of the soil rises from 60 mg. nitrogen per 100 gm. soil to 80 mg. nitrogen on the addition of compost ; and at the higher level, the tendency for further nitrogen fixation may be lessened. It is also possible that loss of nitrogen may take place from the decomposing compost and thus decrease the overall nitrogen fixation figures.

Changes in available nitrogen

The data presented in Table V show that the rate of liberation of 'available nitrogen' (ammoniacal plus nitrate nitrogen) and the total quantity liberated, vary inversely with the C/N ratio of the added material—the narrower the C/N ratio, the greater are the rate and quantity of available nitrogen produced.

Comparing the present data with the figures given in Table II for soil alone, it would be seen that except in the case of composts F and I, which possess C/N ratios wider than 20 : 1, in other cases the application of composts has proved beneficial in increasing the quantity of available nitrogen produced in the soil. Compost H with a C/N ratio of 17 : 1 is on the marginal line, the quantity of available nitrogen produced being almost the same as in the untreated soil. Compost F with a C/N ratio of 21.2 shows an initial period of depression of available nitrogen extending over the first eight weeks, after which the system becomes 'normal' and equal to the untreated soil. In the case of compost I (C/N ratio, 33.4), the period of depression extends over more than 20 weeks.

It is evident from the above that composts F, H and I with C/N ratios wider than 15 : 1, would not react beneficially on crop growth, but on the other hand, may react harmfully by depressing the formation of available nitrogen in the soil, unless a long period of decomposition, extending over four to six months, is allowed to elapse before the succeeding crop is put in.

Influence of method of preparation on the rate of decomposition

A perusal of the data presented in Table V would indicate that the method of preparation of compost exerts its influence on the rate of decomposition of the manure in the soil, mainly by way of controlling the C/N ratio of the compost prepared. Thus the aerobic method, involving several turnings given to the material, gives a product of the narrowest C/N ratio, while the hot fermentation method gives products of somewhat wider C/N ratios and the 'anaerobic' method, as described in this paper, gives products of the widest C/N ratios. The nature of the waste material determines also to a certain extent the C/N ratio of the compost prepared. Thus, compost G, prepared aerobically from a resistant type of waste material such as sugarcane trash, possessed a wider C/N ratio (13 : 8) than compost B (12 : 4) prepared from town refuse and night-soil by the hot fermentation process.

Comparing composts A, B, D, E and G, all of which possess C/N ratios lying within the range 10 : 1 to 14 : 1, it would be noticed that the total quantity of available nitrogen produced in a period of 8 to 12 weeks is maximum in the case of composts A and B prepared from night-soil and town refuse. Composts D and E prepared from mixed farm wastes including leaves, weeds, dung and urine, give somewhat lower values, whereas compost G, prepared from sugarcane trash, shows the lowest value. It is noteworthy that though compost G has a C/N ratio (13.8) narrower than that of E (14.2), still it shows a poorer performance than the latter.

The present data offer an explanation for the better crop response obtained by the writers from night-soil-town refuse composts in pot culture experiments, as compared to other types of composts, even though the C/N ratios were more or less similar in all cases.

Discussion

The results presented above would indicate that the two important factors which control the rate of release of nitrogen in an available form from compost manure are : (i) the C/N ratio of the manure and (ii) the nature of the original waste material or starter used for compost-making. The actual method of preparation of compost exerts only an indirect influence by controlling the C/N ratio of the final product obtained.

Of the above two factors, the first one relating to the influence of C/N ratio of a material on the rate of liberation of ammoniacal nitrogen has been already examined in detail by workers in the field. Richards *et al.* [Hutchinson and Richards 1921; Rege, 1937; Richards and Norman, 1931] found that when the nitrogen content exceeded about 1·6 per cent on the dry basis, the material contained in general more nitrogen than what was actually needed for its microbial decomposition and the excess was set free in the form of ammonia. Expressing the above results in terms of C/N ratio, it may be stated, that when the C/N ratio was narrower than 25 : 1, the material usually liberated a portion of its nitrogen in the form of ammonia, when subjected to microbial decomposition.

The above relationships apply mainly to plant materials which are unfermented to start with. The present experiments with composts go to show that composts possessing C/N ratios narrower than 15 : 1 tend to liberate 'available nitrogen' and thus to increase soil fertility, while composts

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possessing wider C/N ratios tend to absorb 'available nitrogen' from the soil, and thus to decrease soil fertility though temporarily. To ensure a satisfactory rate of release of 'available nitrogen' from the very early stages of decomposition, it would be preferable to have the C/N ratio of the compost narrower than 12 : 1.

As regards the second factor, viz. the influence of the nature of the original waste material or starter used for compost making on the rate of liberation of 'available nitrogen' from the compost, its importance does not appear to have been stressed by previous workers in the field. The general view at present is that when plant materials of diverse composition undergo microbial decomposition, they yield ultimately a more or less similar type of humified material—a ligno-protein complex, with a C/N ratio near 10 : 1 and possessing definite properties [Waksman, 1938]. But it is well known that the final product obtained is not homogeneous, but is a complex mixture consisting in the main of two groups of substances, viz. (*a*) unattacked residues of the original plant materials, and (*b*) synthetic and degradation products of microbial metabolism.

The quantitative distribution of the nitrogen originally present in the refuse or starter, between the above two groups (*a*) and (*b*) in the ultimate compost has not received much scientific attention. It is suggested by the authors that the variation in the rate of release of available nitrogen from composts possessing similar C/N ratios, noted in the present paper, may be accounted for by the differential distribution of nitrogen between the above groups (*a*) and (*b*). Thus, in the case of a compost prepared from sugarcane trash and dung, it is possible that a large part of the nitrogen present in the compost may belong to the group (*a*), representing resistant proteins of the original trash not broken down by the micro-organisms, whereas in the case of composts prepared from night-soil or from cattle wastes or from succulant material such as leaves and grass, a good portion of the final nitrogen of the compost may be microbial nitrogen belonging to the group (*b*). It has been found [Waksman, 1931] that microbial nitrogen is readily ammonified and nitrified.

Further work is being carried out by the authors in order to devise methods for estimating quantitatively the two groups (*a*) and (*b*) present in different types of compost material and comparing the rates of liberation of available nitrogen from them.

Summary

1. The course of decomposition of composts, prepared under varying conditions, when added to soil has been followed, with special reference to changes in carbon and in ammoniacal, nitrate and total nitrogen.

2. The influence of the following factors on the course of decomposition has been examined :

(*a*) method of composting—aerobic, hot fermentation and anaerobic ;

(*b*) C/N ratio of the compost, and

(*c*) nature of the original waste material or starter used in preparing the compost.

3. A red loam garden soil, used in the present experiments, when incubated without the addition of compost, was found to fix about 6 to 8 mg. nitrogen from the air per 100 gm. soil, corresponding to about 10-15 per cent of the initial nitrogen content of the soil. With regard to carbon, there was an initial period of fixation from the air, followed by progressive loss in the later stages.

4. In the soil-cum-compost system there generally occurred an initial period of nitrogen loss, followed by a longer period of nitrogen fixation from the air. The extent and duration of the initial loss of nitrogen was found to be greater, the narrower was the C/N ratio of the added compost. When the C/N ratio was wider than 15 : 1 the loss of nitrogen was negligible ; on the other hand, appreciable fixation of nitrogen from the air occurred. The total quantity of nitrogen fixed by 100 gm. of soil was, however, less in the presence of added compost than in its absence.

5. When composts of varying C/N ratios were added to the soil, the rate of loss of carbon was greater in the case of materials of wider C/N ratios, and in about 20 weeks, a more or less similar carbon level corresponding to a C/N ratio of about 10, was rapidly reached in all cases.

6. The rate of liberation of 'available nitrogen' (ammoniacal plus nitrate nitrogen) in the soil-cum-compost system, depended mainly on two factors, viz. (*a*) the C/N ratio of the compost added —the narrower the C/N ratio, the quicker and greater was the liberation of available nitrogen ; and

(b) the nature of the original waste material or starter used in the preparation of the compost. Thus, composts prepared from night soil and town-refuse or from cattle wastes were found to liberate a greater proportion of available nitrogen than composts prepared from resistant types of farm wastes, such as sugarcane trash, though the C/N ratios of the composts were about the same in all the cases.

7. The method of preparation of compost—aerobic, hot fermentation or anaerobic—influences the rate of liberation of 'available nitrogen' only indirectly by controlling the C/N ratio of the manure obtained by the method in question.

8. It is concluded that for securing a rapid liberation of available nitrogen and thus obtaining increased crop yields, composts should preferably be prepared from mixed wastes, part of which should be rich in nitrogen, e.g. night-soil, urine, cattle-dung, slaughterhouse wastes, etc., otherwise special organic or inorganic nitrogenous starters should be added while preparing the compost. The final C/N ratio of the compost should preferably be narrower than 12 : 1.

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OBSERVATIONS ON JUTE AND CELLULOSE-DECOMPOSING MICRO-ORGANISMS

I. THE EFFECT OF THE NUTRIENT MEDIUM ON THE SPORULATION OF *CHAETOMIUM CHARTARUM* BERKELEY AND *CHAETOMIUM GLOBOSUM* KUNZE

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During the storage of a culture of *Chaetomium chartarum* Berkeley which had been isolated from an active perithecial growth on raw jute fibres it was observed that growth and sporulation were markedly affected by the nature of the medium on which successive subcultures were made. Because of the possibility that synthetic media might not be suitable for full characteristic development of this

strong jute-fermenter, the species was transferred from Czapek-Dox medium to potato slant. Subcultures were subsequently continued on this medium and when next examined after some 6 or 7 subcultures on the potato medium it was suspected that the culture had lost, or nearly lost, its ability to produce sexual spores, even when grown on cellulose, although conidia seemed to be produced in profusion. This particular species is an important one in relation to jute which seems to be its natural habitat and on which it grows very easily with damage to the fibre. It was decided, therefore, to study systematically its reproductive properties in relation to the nutrient medium with a view to selection of a suitable medium for storage in characteristic conditions. Along with this degenerate strain (Lab. No. 58), two freshly isolated species were included in the experiments. These were *Chaetomium chartarum* Berkeley (Lab. No. 75) isolated from the same source and subcultured only twice on cellulosic media before test and the important cotton-destroying species, *Chaetomium globosum* Kunze (Lab. No. 79) isolated from an active perithecial growth on brown paper in contact with moist soil, subcultured only once, on cellulosic medium before test.

Description of species

Short morphological descriptions, obtained from examination of the mature first cultures on cellulose agar, of the two freshly isolated species are given below.

Ch. chartarum (*Lab. No. 75*). Perithecia black to naked eye, deep brown under the microscope, with hairs, brown, septate, roughened, incrusted, reticulately branched. Ascospores smooth, ends pointed, boat-shaped but quickly distending to roundness at the middle when mounted in lactophenol, measuring $5\text{-}5{\cdot}5\mu \times 4\text{-}4{\cdot}5\mu$ when flat. Conidiophores short, pointed, swollen in the middle, usually single, bearing a long chain of conidia at the tip. Conidia round, spinulose, dark brown when mature, $3{\cdot}25\mu$ in diameter.

Ch. globosum (*Lab. No. 79*). Secretes a yellow to brown pigment. Perithecia dark olive green and visibly bigger than those of No. 75, brown, with a scaly surface under the microscope, with hairs, highly coiled, highly incrusted, unbranched, septated. Ascospores smooth, ends pointed, boat-shaped, measuring $9\mu \times 7{\cdot}5\mu$ when flat, minimum breadth $3{\cdot}5\mu$. Conidial colony on Czapek's agar grey green when young, darker when old. Conidiophores short, pointed, swollen in the middle, bearing a long chain of conidia at the tip. Conidia round or slightly lemon shaped when mature, roughened, usually $2\text{-}2{\cdot}5\mu$.

Experimental

Four media were selected as mentioned below.

1. Potato slant.
2. Czapek-Dox agar with cane sugar and K_2HPO_4.
3. Filter Paper partly immersed in an inorganic salt solution of the composition

$NaNO_3$	0·5 gm.
K_2HPO_4	1·0 gm.
KCl	0·5 gm.
$MgSO_4 7H_2O$	0·5 gm.
$FeSO_4 7H_2O$	0·01 gm.
Distilled water	1000 c.c.

4. Cellulose agar, prepared by making a 1 per cent suspension of precipitated cellulose (from filter paper) in Czapek-Dox agar as in No. 2 but without sugar.

Several generations were successively subcultured on each of the media in order to follow any tendency towards reactivation or degeneration as the case might be and the incubation of any one generation was continued until it was evident that no further growth took place.

Incubation was made at room temperature, the whole test covering a period of one year. It was realized that temperature might have a considerable influence on the form of sporulation but

more or less consistent results were obtained thus enabling certain broad generalizations to be put forward. The results are given in Table I.

TABLE I

Sporulation on different media

Medium	Lab. No. 58 *Ch. chartarum* Berk., degenerate strain	Lab. No. 75 *Ch. chartarum* Berk., fresh strain	Lab. No. 79 *Ch. globosum* Kunze, fresh strain
Potato slant	Only conidia (8 generations)	Mainly mycelial; growth of perithecia stunted and spasmodic (9 generations)	Mainly mycelial; growth of perithecia stunted and spasmodic (8 generations)
Czapek's agar	Largely conidial; develops stunted hairless perithecia on continued subculture (7 generations)	Norma perithecia to start with; conidia also appear on continued subculture (7 generations)	Exclusively and profusely grey-green conidial colony (8 generations)
Filter paper medium	Conidia and stunted perithecia to start with, gradually giving place to big hairless perithecia only on continued subculture (6 generations)	Exclusive growth of normal perithecia (8 generations)	Exclusive growth of normal perithecia (7 generations)
Cellulose agar	Largely conidial with very few stunted perithecia to start with; on continued subculture perithecia become fuller with rudimentary hairs which sometimes show signs of reticulation (6 generations)	Exclusively normal perithecia to start with; conidia also appear on continued subculture (8 generations)	Exclusive growth of normal perithecia (8 generations)

It was also observed that inoculation with only conidia or ascospores had no effect on the preponderance of these two forms of sporulation on the subsequent culture.

Pure culture experiments designed to estimate the relative cellulose decomposing capacities of these species were carried out by inoculating after sterilization, weighed pieces of filter paper just immersed in an inorganic salt solution contained in small conical flasks. After incubation at 30°C. for 30 days, the residue was filtered on a weighed sintered glass crucible, washed, dried, conditioned and the crucible weighed. The results are given in Table II.

TABLE II

Relative cellulose—decomposing capacity

Laboratory No.	Per cent loss in cellulose
58	17
75	54
79	46

Discussion

From Table I it appears that for *Ch. globosum* the best medium for conidial growth was Czapek's agar ; for growth of normal perithecia both the filter paper medium and cellulose agar were equally good. It has not been possible to get simultaneous development of conidia and perithecia in any of the four media through eight generations.

The cultural behaviour of *Ch. chartarum* appears to be rather more complicated. Filter paper medium will give full perithecia, while continued subculture on cellulose agar will give conidia in addition. Continued subculture on either Czapek's agar or potato tends to increase mycelial and conidial growth at the expense of sexual spores. Transfer and repeated subculture on some cellulosic medium of strains ' degenerated ' by successive germination on these media will show a gradually growing tendency to perithecia formation, but restoration of fully developed perithecia, if possible, is slow. During any such process of restoration the same tendency of cellulose agar to support both conidia and perithecia, and of filter paper to support perithecia only is also observed.

It appears therefore, that these two species of *Chaetomium* can be preserved in what is known as the perfect state on either a strip of filter paper partly immersed in Czapek's solution without sugar, or cellulose agar containing 1 per cent regenerated cellulose. The former has the advantage of being easier and quicker to make up, while the latter has the advantages of a solid medium and in the case of *Ch. chartarum*, of producing conidia simultaneously with sexual spores. It is also seen that Czapek's agar and potato (and therefore, probably cane sugar and starch) encourage the formation of the vegetative or imperfect stages.

It is to be remembered that these conclusions are not in any sense absolute ; different results might be obtained at different temperatures and from a larger number of generations.

The figures in Table II are of interest because they establish quite clearly that the decomposition of cellulose and the production of perithecia appear to be closely related, which, in its turn, emphasizes the extreme importance of selecting the proper medium for storage purposes—especially, because the use of a pure culture of a *Chaetomium* species (e.g. *Ch. globosum*) is being increasingly advocated for testing the microbiological decay of textiles. [A.S.T.M. standards, 1942 ; Greathouse, Klemme and Barker, 1942 ; Thom, Humfeld and Holman, 1934].

Also, apart from many obvious objections against this method being accepted as a standard, it may be mentioned that at least in the special case of jute, *Ch. globosum* plays little or no part in its deterioration. During the course of several years it has never been found growing on jute nor has it hitherto been isolated from artificially rotted jute fibres or mildewed jute goods of which numerous samples have been examined. The contrary however, is found to be the case with *Ch. chartarum* which has never failed to make an appearance every time jute fibres or materials have been incubated over water. If *Ch. globosum* is native on cotton, *Ch. chartarum* appears to be its counterpart on jute and under the conditions of the particular test described it also appears to dissolve more cellulose quantitatively than *Ch. globosum*.

Summary

Chaetomium chartarum has been found to be native on jute fibre and also a strong jute-fermenting fungus. Along with the well-known cotton destroying species *Chaetomium globosum*, this species has a distinct preference for cellulose as its source of carbon and would otherwise degenerate into the imperfect stage from which it is difficult to revive. It is also found that dissolution of cellulose is directly dependent on production of perithecia in the case of *Ch. chartarum*. Two cellulose media giving vigorous perithecial growth have been found satisfactory for continued growth and storage of these two species.

Acknowledgements

The author is indebted to the Committee of the Indian Jute Mills Association Research Institute for permission to publish the results described and to Dr W. G. MacMillan for assistance in compiling the paper.

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PRELIMINARY STUDIES OF THE NUTRITIONAL DISEASES OF PLANTS AND THEIR SPECTROSCOPIC DIAGNOSIS

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(With Plates XIII-XVI and one text-figure)

The intensive study of crop nutrition has brought to light numerable deficiency diseases and a new science is being built up on the nutritional diseases of crops. Symptomatic diagnosis of deficiency diseases is not easy and even when done touches only the fringe of the problem, as the symptoms are the result of the disease and not the cause. The same symptoms could, therefore, be produced by a variety of unrelated causes, e.g. an excess of one element can cause, by its particular nature, an apparent deficiency of another although no such deficiency actually exists in the soil. In other circumstances the same agent may cause a variety of symptoms depending upon its intensity. The deficiency of minor elements in Indian soils, both real and induced, forms a fruitful subject for investigation and its importance has been pointed out by Kharegat [1943].

The methods of determining mineral deficiencies in crops have been reviewed by Wallace [1943]. They are as yet not fully developed and no one method can be relied upon to give authentic data. It is, therefore, necessary to supplement symptomatic diagnosis by other corroborative analytical data. The pot culture experiments, including the addition or withholding of some mineral nutrients, have been found to be time-consuming and even sometimes misleading. The purely chemical analysis of plants and soils, although less time-consuming, would not cover the possibility of an unsuspected element causing the trouble. This has lead to the development of spectro-chemical methods which while eleminating this defect have the advantage of speed. The preliminary studies presented in this paper have been undertaken for employing the spectro-chemical methods to explain some of the peculiarities met with in the crops chiefly at the Institute farm and to supplement these findings where necessary with pot culture experiments.

Methods of spectroscopic analysis

The arc spectra on an E_2 (Adam Hilger's) spectrograph were obtained as follows: A one-gram sample of the soil after the usual sampling procedure was treated with 3 c.c. of concentrated nitric acid of tested purity in a platinum dish and evaporated on a water bath to a consistency of a thick paste. A representative sample from this was put on H. S. copper electrodes and the spectra of the samples that were to be compared, containing the characteristic lines of the different elements, were taken in juxta-position by means of the Hartman's diaphragm. By controlling the distance between the electrodes, their diameter, the current and voltage and the time of exposure on the photographic plate, the visual intensity of the lines in the spectra could be made to correspond with the concentration of the elements in the samples. Therefore, there was no need for the quantitative measurements of the line intensity in terms of an internal standard for the purpose of this diagnosis. The plant materials were also sampled in the usual way, ashed and then treated as the soil sample above. In cases where quantitative results were necessary, these were obtained after microphotometry and comparison of the unknown was effected with suitable known standards by the method of the internal standard of Gerlack and Sweitzer [1938].

The photographic plate gave more information than could be reproduced in the prints. However, many of the salient features have been brought out in the prints presented in this paper. Plates XIII and XV show some enlarged prints which give an idea as to the clear way the plates look under an eye-piece. The characteristic lines for boron at 2497·73 and 2496·78 A° are very close and are shown as faint lines near about 40·3 on the reference scale at the bottom of which is marked B. The strong magnesium line 2795·54 A° is shown at about 36·0 on the reference scale with the letter Mg. marked at the bottom. At another place also (26·2 on the scale) there are fainter magnesium lines at 3832·31 and 3838·29 A°. These are more indicative when the first and strong magnesium line is too deep to give details of small variations. Immediately to the right of the above mentioned deep magnesium line and very close to it near the scale reading of 36·0, there is a faint manganese line at 2798·27 A° at the bottom of which is marked Mn. Sometimes another but fainter manganese line is also marked at 30·1 much to the left of this line, being the second one to the left of a strong copper line. A faint zinc line is sometimes marked at 30·1 and another faint one at 21·4 between the last two of the deep triplet lines of copper. At the bottom of these are marked the letter Zn. The iron lines between 28·2 and 28·4 on the reference scale refer to those at 3570·10 and 3581·20 A° and carry the letter Fe pointing to them. The two strong calcium lines at 25·3 and 25·6 carry the letter Ca, while the finer lines at 22·5 and to its left are also marked Ca but lie on extreme right of the first set. The potassium lines 3446·72 and 3447·70 between the two deep copper lines at 24·8 and 25·0 on the reference scale are very close and carry the letter K at the bottom. From a comparison of the intensities of these lines in the healthy and diseased portions some of the plant diseases were studied and are detailed below crop-wise.

Tobacco

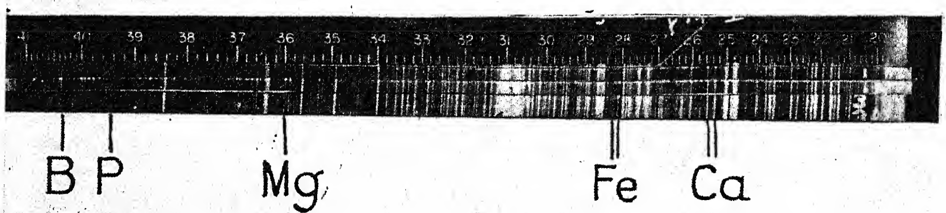
In the tobacco fields, in 1943 at the Imperial Agricultural Research Institute, New Delhi, there were many plants with the younger leaves composing the bud exhibiting a lighter green colour compared to their tips. These had a drawn out appearance, while some of them had a one-sided distortion or twisting. These symptoms corresponded with the boron deficiency symptoms of tobacco described by McMurtray [1938].

However, an actual boron deficiency in the soil could not be expected as the Delhi soil contained 35 p.p.m. of boron in it. It was, therefore, thought necessary to confirm this symptomatic diagnosis by analysis and also by simulating the conditions of this induced boron deficiency by growing tobacco in pots under conditions of varied nutrient balance. For this purpose heavy doses of N,P_2O_5, K_2O in 100,50 and 285 lb. per acre respectively and their various combinations, each with and without the addition of minor elements, were added to the soil in quadruplicate pot experiments with tobacco. The minor elements added were a combination of $CuSO_4$, zinc acetate, boric acid and manganese sulphate at the rate of 2/3 lb. per acre. Selected seedlings of adcock obtained by kind courtesy of the Imperial Economic Botanist were transplanted early in November. By January definite deficiency symptoms were produced in some of those plants.

The spectra of the leaf (3A) showing the above-mentioned type of symptoms (suspected to be boron deficiency) compared to that of a healthy leaf (3) of the same physiological age (3rd leaf from the top) are shown on Plate XIII, where the intensity of the lines is proportional to the concentration in the sample of the element whose chemical symbol has been marked below that line. They are found to show a boron deficiency. These leaves had 38·7 and 65·7 p.p.m. of boron on dry basis. A leaf tip injection of 0·005 per cent boric acid was given for 24 hours to a leaf and one of distilled water to another leaf to serve as control. The boric acid injection restored the colour of the leaf compared to the control, which still retained the previous symptoms. The boron deficiency was thus confirmed.

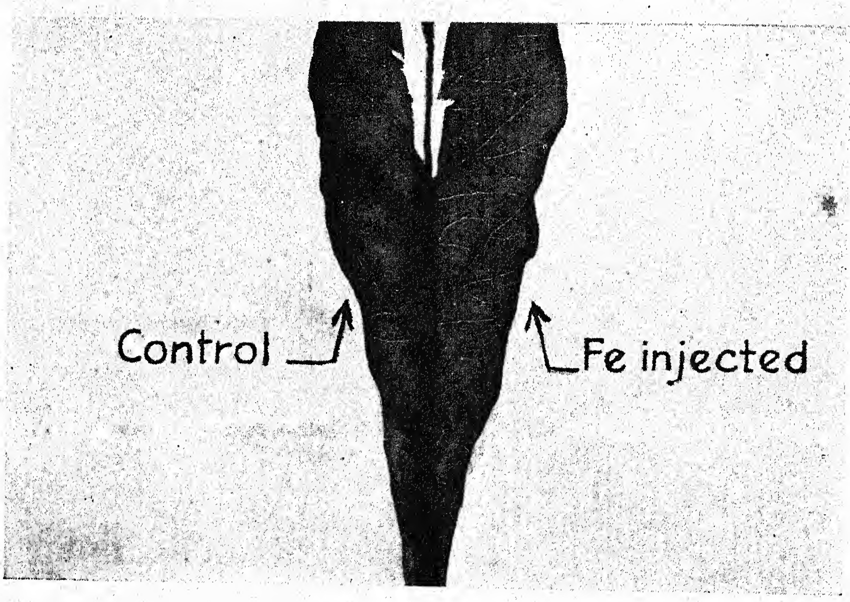
These symptoms appeared in all the pots treated with K and to a less extent with K+N suggesting that it was an excess of K which had caused this boron deficiency. This can be explained on the basis of an unfavourable Ca/K resulting from this excess of potassium as a close association between Ca and B in the plant has been reported by Warrington [1934]. This is supported by the line intensities of the various elements in 3 and 3A on Plate XIII. The spectra of the chlorotic leaf containing less boron also shows less Ca and slightly more of K, Mg., Fe., Mn. and P compared to the

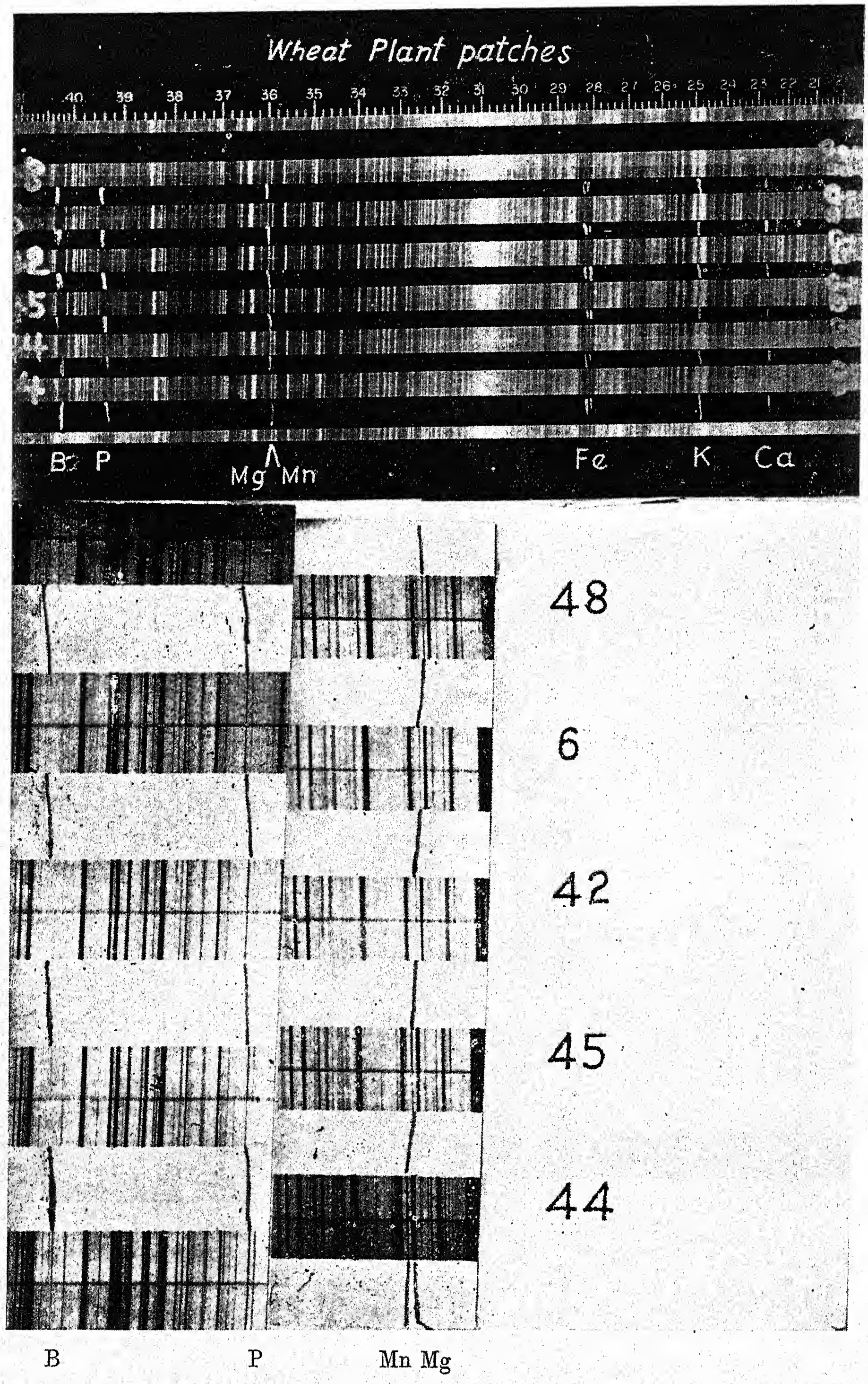
1. Diagnosis



Note Fe deficiency in 1A and B deficiency in 3A compared to 3 which is healthy. Below is shown the beneficial effect of Fe injection on one half of 1A leaving the other half as control showing chlorotic and patchy appearance between the darker veins.

2. Cure by injection





Note the deficiency of Mn, B & Ca in the lower one (belonging to the unhealthy leaves) compared to the top one of each pair of spectra. The differences correspond with the extent of the disease. Below are shown enlargements of portions of the above on the negative to show them more clearly.

healthy leaf. Table I gives these results quantitatively in terms of the logarithm of galvanometer deflection which is proportional to the concentration of the element in the sample and which bear this fact.

TABLE I

Analysis of tobacco leaves (values in terms of log. galvanometer deflections)

Description of sample	Mg value	Ca value	K value	Fe value	Mn value	Percentage Mn on dry basis in p.p.m.	Percentage B on dry basis in p.p.m.
1—Fe injected and cured half of the leaf minus midrib	$\bar{1}\cdot818$	$\bar{1}\cdot895$	$\bar{1}\cdot539$	$\bar{1}\cdot353$	$\bar{2}\cdot957$	4·35	..
1A-Diseased half of the leaf minus midrib	$\bar{1}\cdot947$	$\bar{1}\cdot871$	$\bar{1}\cdot652$	$\bar{1}\cdot229$	$\bar{1}\cdot484$	1·3	..
3—Healthy leaf . . .	$\bar{1}\cdot826$	$\bar{1}\cdot953$	$\bar{1}\cdot993$	$\bar{1}\cdot806$	$\bar{1}\cdot041$	..	65·7
3A—Leaf showing symptoms of boron deficiency	$\bar{1}\cdot911$	$\bar{1}\cdot947$	$\bar{1}\cdot996$	$\bar{1}\cdot880$	$\bar{1}\cdot521$	..	38·7

Another type of chlorosis was found affecting the young leaves in some of the other pots. The leaves presented a clear pattern of greener veins on a chlorotic or lighter green back ground corresponding to McMurtrey's description of iron deficiency. The spectra of the chlorotic portion 1A along with that of the healthy leaf 3 is given on Plate XIII which shows an iron deficiency. A Roach's [1939] leaf tip injection of 0·05 per cent ferric sulphate was given for 24 hours to one half of the leaf, leaving the other half on the other side of the midrib as the strictest possible control which received only distilled water injection. This made the injected portion recover its colour in the chlorotic patches between the veins, while the control remained chlorotic as before. The photo of these two portions of the leaf with their spectra are shown on Plate XIII. The analytical data in terms of the log. of galvanometer deflection which is proportional to the concentration of the elements are given in Table I.

From the differences in the composition of 1A and 3 and 1 and 1A, it is seen conspicuously that the iron deficiency is accompanied by a manganese excess. This excess seems to be the cause of the disease as the iron injection which caused the cure lowered the Mn content while a manganese injection to a chlorotic leaf only aggravated its condition.

These symptoms are the same as those reported by Jacobson and Swanbuck [1929] for Mn toxicity. Bartner [1935] cured the disease by the application of phosphatic manures to the soil, McCool [1913] by K and Johnson [1924] by Fe. This literature only indicates how misleading the plant responses to manures are sometimes in respect of the deficiency diagnosis. It may be that those manures had only secondary reactions which actually corrected the excesses, which in turn were responsible for a deficiency. Thus it is possible that the same cause namely Mn excess might have induced one or more deficiencies according to the extent of this excess and the specificity of the crop. Here again the limitations of the symptomatic diagnosis are brought to light as it could show only the iron deficiency but not the Mn excess which was the cause of this deficiency. Johnson [1924] working in Hawaii associated the Fe deficiency with a Mn excess and suggested a theory to account for the unavailability of iron between pH 4·4 and 7·0 in the presence of an excess of MnO_2 in the soil. In order to see if the same is the case under study, the *p*H of the soils in relation to this chlorisis is given in Table II as determined electrometrically by the antimony electrode.

TABLE II

Soil pH in relation to manganese induced iron deficiency

Pot No.	Treatment	pH of the soil by antimony electrode	Occurrence of the disease
101	K+P	7·98	—
103	K+P	8·02	—
102	K+P+m	7·46	—
104	K+P+m	7·63	+
105	N+P+K	7·6	+
107	N+P+K	7·79	+ (Slightly)
106	N+P+K+m	7·29	—
103	N+P+K+m	7·36	—
109	N+P+K	7·98	—
111	N+P+K	7·67	+
110	N+P+K+m	7·71	+
112	N+P+K+m	7·36	—

Although definite *pH* limits from 7·5 to 7·8 are suggested for this disease from Table II, they are much higher than the limits found by Johnson [1924] and therefore require a different explanation. From this Table, it is found that as a result of the iron injection, almost all the positive ions excepting Ca are lowered by the entry of iron which seems to suggest a simple ionic mass antagonism. On this basis the Fe deficiency seems to have been caused by the excess by simple ionic exchanges.

WHEAT

In some of the manurial experimental plots of the Institute, good and bad patches of considerable magnitude were observed. Fig. 1 obtained by kind courtesy of Mr R. D. Bose shows the nature of the stand of the crop in the different plots. This disease affected *jowar* and wheat and showed a consistency in the location of the patches indicating a relation to the soil at those places. The symptoms of the disease were very stunted growth and chlorotic spots or streaks which ranged in colour from white, whitish yellow to yellowish green. Sometimes there were lesions which in extreme case coalesced and the leaf was bent down at those places. The earheads, when they emerged, were found to be stuck up to the stems at the top. Table III gives the values of fresh weights of 20 flag leaves of wheat grown with different kinds and doses of nitrogenous manures from some of the patches, their ash, loss on ignition and nitrogen content, which shows that the diseased plants absorbed more mineral matter than they could convert into organic forms or probably that their carbohydrate and protein metabolism had been interfered with.

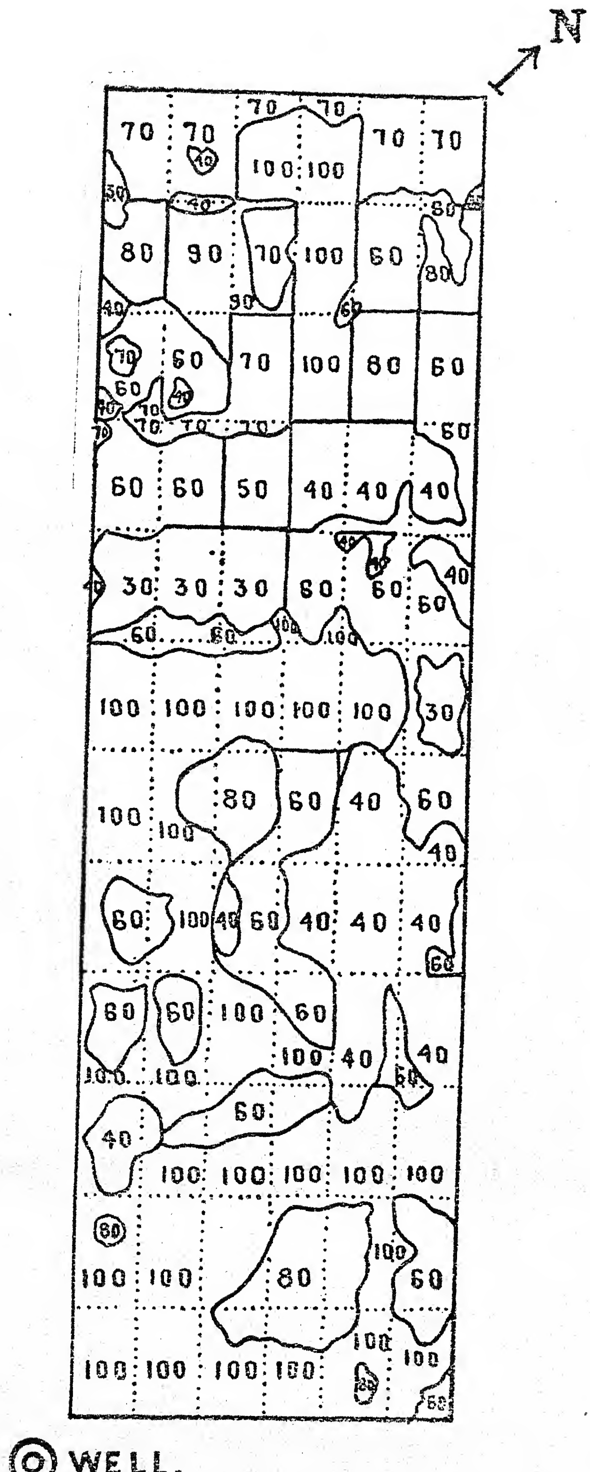


FIG. 1. Patchy appearance of the plots. The numbers indicate the nature of crop stand as percentage of normal stand as on 6-1-1944.

TABLE III

Wheat plots 1943-1944

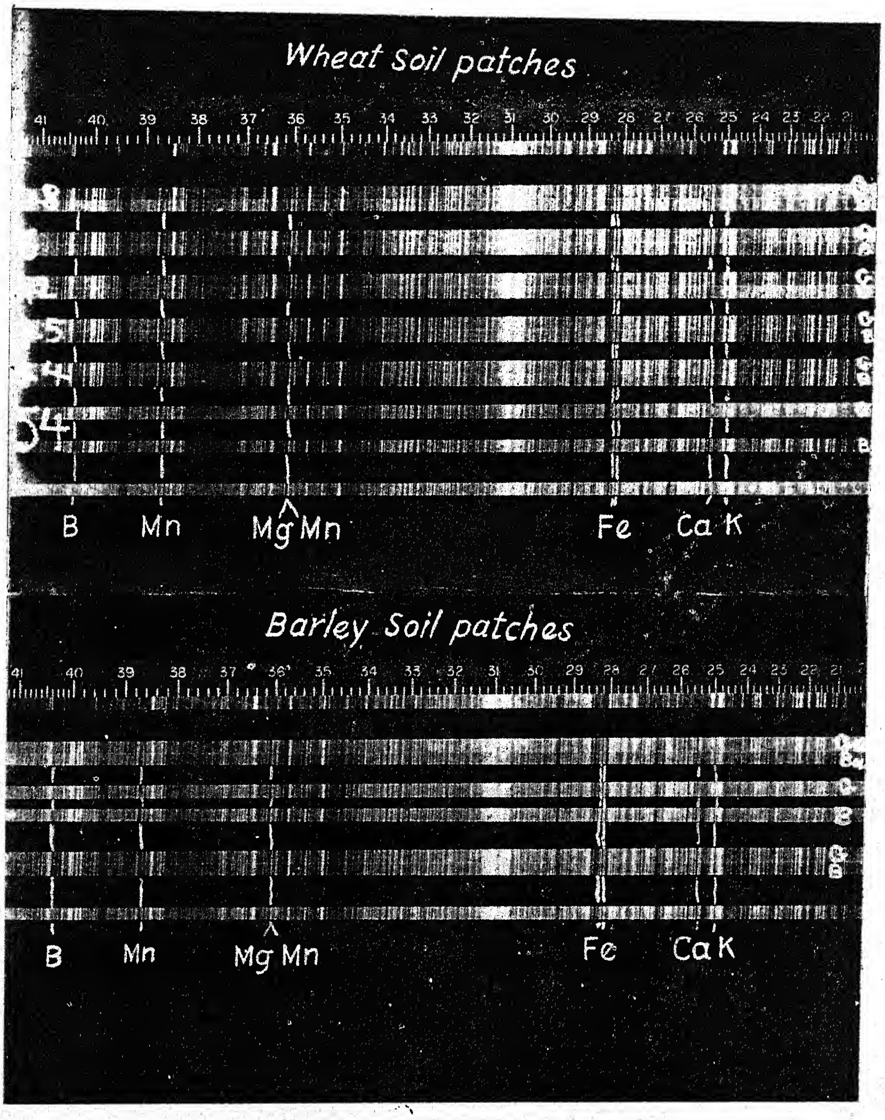
Soil Plot No.	Nature of the patch	Fresh wt. in gm. of 20 flag leaves	Loss on ignition (percentage on dry basis)	Percentage ash on dry basis	Percentage of N on dry basis
6	Good	8·25	85·7	14·3	..
	Bad	3·2	84·0	16·0	..
42	Good	6·65	87·2	12·8	3·06
	Bad	3·25	84·0	16·0	2·70
45	Good	7·3	90·9	9·10	3·72
	Bad	1·8	86·2	13·8	3·22
44	Good	5·7	90·0	10·0	3·99
	Bad	3·8	86·1	13·9	3·59
54	Good	6·2	87·4	12·6	3·00
	Bad	3·65	85·7	14·3	2·94

These symptoms do not correspond with any of the recorded deficiency symptoms although they have some features of the Mn deficiency. Such a difficulty with the symptomatic diagnosis has been recognized by Wallace [1943]. So composite samples of flag leaves were taken from both the good and bad patches and the foliar diagnosis was made spectrochemically. Plate XIV contains the spectra of these samples. The intensities and therefore the percentages of Mn and B of the lines were consistently lower for the samples from the bad patches while the relation for P, Mg and Fe was irregular. Only Ca tended to be low and K to be higher in the diseased plants. That both Mn and B showed a deficiency has the parallel in the French experience quoted by Dennis [1937] that a soil showed a B deficiency for beet and a Mn deficiency for oats. In the case of these samples the Mn lines seem to follow the order of differences between the good and bad patches. In the plots showing smallest difference in the Mn line (i.e. Plot No. 48) there was also not much difference in the plant height in those patches. This diagnosis reveals the similarity of this with the grey speck disease caused by a deficiency of manganese studied by Hudig [1911] and Samuel and Piper [1928]. This is supported by the *p*H values of these soils (Table IV) which are all alkaline, the bad patches generally showing slightly higher *p*H. The cause of this disease, its mechanism and cure are under investigation.

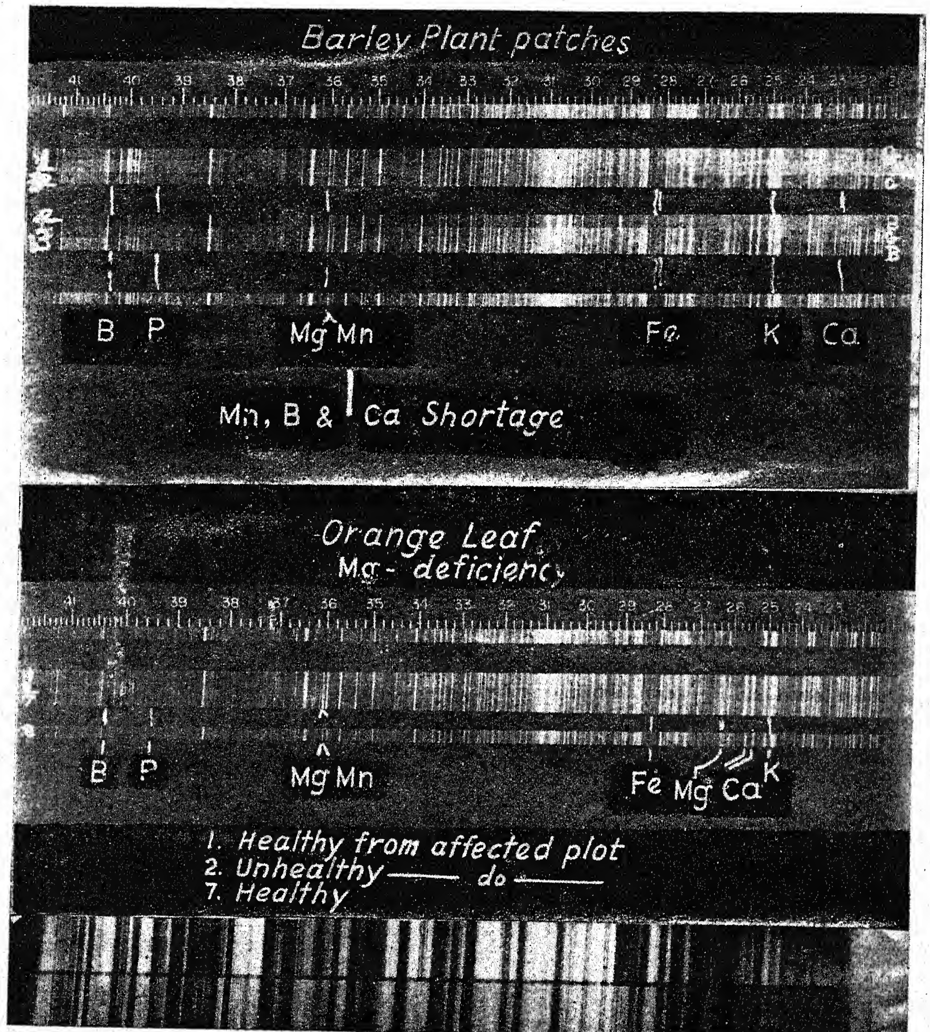
TABLE IV

*p*H *of the good and bad patches of wheat soils by the antimony electrode and the clay content by Puri's method*

Plot No.	Nature of patch	*p*H value	Percentage of the clay
6	Good	8·02	6·99
	Bad	8·09	7·09
42	Good	8·0	5·79
	Bad	8·01	6·33
45	Good	8·09	6·73
	Bad	8·18	6·67
44	Good	7·79	6·73
	Bad	8·09	6·90
54	Good	8·21	..
	Bad	8·17	..
48	Good	8·09	..
	Bad	8·14	



In these spectra G refers to the good & B to the bad soil samples. The minor element deficiency shown by the plants are however not shown by their soils but there is an indication of a K excess in the bad samples which is responsible for the minor element deficiencies in the plant.



Zn

G & B on the spectra refer to good and bad samples. Note the similarity of the disorders in the barley plant patches with those in the wheat plant patches on plate 2.

In the next set, the Mg deficiency in the orange leaf is accompanied by an Fe excess.

The enlarged spectral pair on white background shows the Zn deficiency in the soil carrying the unhealthy betel nut trees compared to its healthy counterpart.

The spectra of the corresponding soils are given in Plate XV which show slightly more of K and probably Ca in the bad patches. The clay contents (Table IV) are also tending to be higher along with the *p*H, which may indicate the direction of the water movements which seem to have a bearing on the cause of this disturbance in the soil. But Mn and B in the soil (Plate XV) do not show the difference they have shown in the plants (Plate XIV). Therefore it is not the total manganese content of the soil but only the available portion which is effective; this was also the case in the grey speck disease studied by Gerretsen [1937] that is responsible for this disease. The fact that the soil from the bad patches is a bit more alkaline containing more of K with a similar increase in the K content of the corresponding plants points to mechanism of the unavailability of Mn as also to the possibility of curing the disease by proper cultural practices alone. Some of the analytical data on the boron and manganese content of these plants and soils are given in Table V.

TABLE V

Analysis of wheat patches

Plot No.	Nature of the patch	Mn in p.p.m. in plant ash	B in p.p.m. in plant ash	Mn in p.p.m. in the soil	B in p.p.m. in the soil
6	Good	42·7	32·7	4·1	17·2
	Bad	34·7	20·0	7·4	30·9
42	Good	53·7	15·31	12·0	24·6
	Bad	16·4	13·8	43·2	14·3
45	Good	74·1	51·3	70·0	4·79
	Bad	27·5	10·0	164·8	13·5
44	Good	171·8	59·6	10·0	7·08
	Bad	80·4	19·9	6·9	100·0
54	Good	102·3	36·3	41·7	3·89
	Bad	25·7	35·5	26·9	2·14
48	Good	35·1	112·00	..	42·7
	Bad	37·1	16·8	38·0	8·9

BARLEY

In the case of this crop the symptoms and nature of the disease were more or less similar to those described under wheat except that the spots were more frequently purplish brown which followed the higher iron content of the diseased leaves as shown in the spectra on Plate XVI. In this crop also the plants from the bad patches showed a deficiency in Mn, B and slightly in Ca and their soils (Plate XV) showed an increase in K and Fe bringing out the complete similarity of the disorder in both the crops. The results are given in Table VI.

TABLE VI

Analysis of barley patches

Plot No.	Nature of patch	Mn in p.p.m. in plant ash	B in p.p.m. in plant ash
1	Good (highly differentiated)	70·8	43·7
	Bad ,, ...	38·9	23·7
2	Good (slightly differentiated)	68·0	27·5
	Bad ,, ...	70·0	15·3
3	Good (moderately differentiated)	57·6	21·6
	Bad ,, ...	38·9	20·6

Citrus (orange)

The Director of Agriculture, Assam, and the Imperial Mycologist reported a common 'yellowing disease' of citrus in that province which manifested itself sometimes as a mottling of yellow on the green leaf, sometimes as a simple chlorosis and finally yellow colouration of the entire leaf. This disease was expected to be a zinc deficiency from the symptoms but experiments for its cure with zinc were not successful. The samples were sent to us through the Imperial Mycologist. On Plate XVI are the spectra of the samples of leaves. Nos. 7 and 8 belong to healthy trees from a healthy and unaffected plantation. Nos. 1 and 2 are from a plantation which was susceptible to this disease, the former taken from the healthy and the latter from the unhealthy trees of that area. An excess of Fe and a deficiency of Mg could be found in spectra of the plant ash. The examination of their soils spectroscopically showed a similar iron excess in the affected area of the soil. This appears, therefore, to be an iron induced magnesium deficiency and points to the desirability of an application of Mg which is capable of suppressing the iron intake of the plant by virtue of its ionic reactions. This is in conformity with the American experience of the association of Mg with Zn deficiency [Kharegat 194:]. The other effects of this disorder are a low nitrogen absorption in the affected plant as shown by their nitrogen contents.

Betelnut

Many plantations in the Bombay Presidency have a disease locally called 'band' which was causing great damage to the betelnut trees. There was an untimely fall of the leaves which assumed a chlorotic appearance with sometimes the setting of 'crowns' or 'rosettes' and the diseased portions did not bear fruit. The samples from some of those gardens were sent to us for analysis by Mr N. V. Joshi. The spectra of the unhealthy soils showed a zinc deficiency while the corresponding leaf showed a manganese excess. One enlarged spectrum of a pair of healthy and diseased soils is shown at the bottom of Plate XVI. Hence a zinc deficiency, probably manganese induced, could be suggested. Subsequently zinc was applied by Mr Joshi and was found to have a stimulating or a corrective influence, while the addition of manganese only aggravated the trouble.

Discussion

In all the cases studied here, there was an invariable association of these deficiencies with an excess of another element, which appears to be the more common way in which these elements are rendered deficient in India. Although there may not be any actual deficiencies in the soils, these were presumably caused by an upset of the nutrient balance in the soil. This is shown by the ionic relations between iron and manganese, where the excess of the latter caused the deficiency in the former while an iron injection into the diseased plant reversed this process in tobacco. A similar mechanism has been suggested by Lundegardh [1934] for the cause of the grey speck diseases in oats and is probably the more common way these deficiencies are established in soils. A suitable remedy could be devised only by knowing the deficiency as well as its cause. As for example zinc deficiency symptoms could not be corrected unless a causative copper deficiency was first corrected [Camp, Chapman, Bahrt and Parker, 1941]. Similar is the case when the deficiency is caused by the excess of another element. The spectrochemical analysis of soils and plants give an insight both into the deficiency and the causative excess if any, while the symptomatic diagnosis at best gives only one. The symptomatic diagnosis is very intricate because different symptoms develop for the same deficiency depending on the nature and extent of the causative excess [Bahrt 1941]; and different deficiencies may also be caused by one and the same cause, e.g. excess of lime, etc. The manurial trials by themselves are only empirical and their success may only be indirect and temporary as they give no clue to the understanding of the cause of the troubles. This is because any of the several manures may affect a temporary remedy by their side reaction with the element in excess, and therefore may appear in the first instance to have corrected the deficiency. In all these cases the analytical method has to be used but this suffers from the drawback that it cannot be handled by the lay farmer.

Summary

1. Some minor element deficiency diseases of tobacco, wheat, barley, citrus and betelnut occurring in India are recorded.

2. In all these cases, the deficiencies were found to be associated with an excess of some other element. Depending on the extent of this excess, deficiencies of some or more elements occurred giving a wide range of deficiency symptoms. This provides the reason for the failure to affect a cure by the consideration of symptoms alone.

3. It was found that the spectrochemical analysis of the affected soils and plants in comparison with their healthy counterparts provided an insight into both the element in excess and the secondary deficiencies.

4. The spectrochemical diagnosis could be successfully used for correcting these diseases.

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PLANT QUARANTINE NOTIFICATIONS

Notice No. 4 of 1945

THE following quarantine regulations have been received in the Imperial Council of Agricultural Research. Those interested are advised to apply to the Secretary, Imperial Council of Agricultural Research, New Delhi.

1. Service and Regulatory Announcements—October-December 1944
2. Service and Regulatory Announcements—October-December 1942
3. Service and Regulatory Announcements—Januray-March 1945

Regarding Foreign Quarantine from the United States Department of Agriculture.

Notification No. F. 15-1/45-A, dated the 12th November 1945, of the Government of India in the Department of Agriculture.

In exercise of the powers conferred by sub-section (1) of Section 3 of the Destructive Insects and Pests Act 1914 (II of 1914), the Central Government is pleased to direct that the following amendment shall be made in the notification of the Government of India in the Department of Agriculture No. F. 15-1/45-A, dated the 25th September 1945, relating to the import of apples, pears and quinces from Afghanistan namely :

In the said notification after the word ' prohibit ' the following shall be inserted, namely : ' with effect from the 1st January 1946 '.

Notification No. F. 15-1/45-A, dated the 12th November 1945, of the Government of India in the Department of Agriculture.

In exercise of the powers conferred by Section 4A of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to direct that the following amendment shall be made in the notification of the Government of India in the Department of Agriculture No. F. 15-1/45-A, dated the 25th September 1945, relating to the export of apples, pears and quinces from British Baluchistan namely :

In the said notification after the word ' prohibit ' the following shall be inserted, namely : ' with effect from the 1st January 1946 '.

GIPC—M—III-1-5—15-11-46—600.

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ORIGINAL ARTICLES

GROWTH STUDIES ON *SACCHARUM OFFICINARUM*

I. VARIETAL SERIES

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(With one text-figure)

In breeding and selection of varieties it is of utmost importance to speed up the process of selection (of an attempted cross at a breeding station) from the stage of a cane seedling to the final stage when it becomes an approved variety fit for distribution to the cane growers. The plant breeders and agronomists are, therefore, now more and more on the look-out for methods that would rapidly facilitate quick selection of varieties. Methods that a few years ago were of fundamental physiological interest have been simplified and modified to suit field environment. Arithmetical procedure to use the physiological data have been reduced to analyseable form. Thus old empirical observational system is rapidly being replaced by newer perfected tests to yield elaborate and accurate information of value regarding the performance of seedlings. Growth in length is one of the important physiological characters of varieties which is interpretable mathematically and which yields information of value for selection of varieties in quick progress. In the paper this aspect has been studied in some detail in the varietal trials.

Historical

Blackman [1919] enunciated that the rate of growth in plants in general may be expressed according to the compound interest law concept. He further elaborated on the subject and established the importance of r as a measure of the relative growth rate even in such cases where growth had not strictly followed the exponential law. He defined r as the rate or an index of efficiency of the plant as a producer of new material. On the subject considerable criticism was advanced by Kidd, West and Briggs [1920] who had already done work on the problem in some detail. Reviewing these objections Fisher [1921] mathematically showed that the correct measure for the value of relative growth rate over long or short periods was that advocated by Blackman under the concept of efficiency index. He asserted that growth at various stages or time intervals and consequently relative growth rate under the influence of any treatment can best be studied by the logistic or exponential equation. Rather he opined that all biological developments are controlled according to the compound interest law, and hence $H= Ae^{bt}$ can work quite satisfactorily to determine the rate of growth and initial potential or development. This authoritative view left little ground for further controversy on the subject and it simultaneously led the scientists to use the exponential law for determining the rate of growth of crops.

In studying the development in *Musa cavendishii*, Lambert variety of Banana, Summerville [1944] examined data on the efficiency of growth of the leaves and observed that the average efficiency index, i.e. r, was virtually constant for all the plants, which seemingly was conferred by virtue of the genetical constitution. The constancy of r was brought about by the fact that normally the final area increased as t increased. He further confirmed the findings of Gregory [1928] that 'The total growth is not the function of temperature and other external factors,' but is, as stated above, conferred by the genetical constitution of the plant.

Koenigs [1922] from measurements of cane at regular intervals showed that the growth of cane is symptomatic of logistic curve and is considerably influenced by temperature and other environmental factors. Ashby [1930, 1932] employed the results of growth rate for working out the hybrid vigour and the inheritance of efficiency index in maize. Heath [1932] fitted curves of exponential

types from the growth measurement data of some of the South African varieties of cotton and observed that a large value of A in the formula $H = Ae^{bt}$ showed high initial potential of growth of the varieties. This was confirmed by Afzal and Iyer [1934] from statistical analysis of exponential height growth curves of four varieties of cotton—4F, 289F, Early Strain and Mollisoni. Further comparison of values indicated that the Punjab American varieties compared favourably in their rate of growth with the South African varieties studied by Heath. Amongst themselves Punjab American varieties had a lesser growth rate than Mollisoni. Besides, they observed a high coefficient of correlation between the relative growth rate and the mean daily growth rate of the varieties for the whole period of study. Willcox [1930, 1938] suggests that by determining the point of inflection of the curve it is possible to state the period of application of readily available plant food that may be effective in increasing the yield of the crop. From the growth values he also suggests a procedure of determining the manurial requirements of the crop for a particular soil type.

Observational growth data have been successfully utilized by various workers for different purposes. Barber [1918] calculated cane module values of Saretha and Sunnabile groups for two years and showed that the Saretha group values were higher than the values of the Sunnabile group of canes. Again the curves, showing the average length of successive joints from the base to the apex in the Saretha and Sunnabile groups, were two distinct types. The former group of canes developed more rapidly than the latter in all their parts. Barber [1919] also (i) reported on the effect of locality on the growth of indigenous canes, (ii) characters of cane growth in different places, (iii) the effect of season on the length of cane joints and (iv) the periodicity in the length of the joints. From these studies he concluded that '.................... not only had each variety a definite growth character of its own but that each locality and soil had the power of modifying this. So that the growth in each place was the resultant of the inherent characteristic of the type and the external environment to which it is subjected.' The measurements of the various characters were made at harvest and the conclusions drawn were purely from the curves and the averages of the such tabulated data. Using Venkatraman's data he [Barber, 1919] drew some important inferences on tillering phase of the growth of the crop, namely, (*a*) the main shoot was thinner and less developed than its branches, (*b*) the different varieties varied greatly in the maturing of canes, (*c*) the branching in the various groups from the wild *Saccharum spontaneum* to the thick tropical canes was of the same nature but of a different degree and (*d*) average thickness of canes in a group varied inversely with the rate of tillering. Agee [1930] by illustrating the growth made in each of the month of the growth cycle mathematically showed the importance of summer-time and winter-time and thus tried to assess 'the relative growing time value of each month in the year' for increasing production of sugar. Das [1933] further elaborated the idea and attempted to determine the production of sugar in terms of temperature or as he termed them 'day degrees'. But one of the most important use to which the growth in length data have been put is the determination of the wilting coefficient of soil. Shaw and Sweezy [1937] have reported the comprehensive field investigations carried out on irrigation requirements in Hawaii, which have for their basis the determination of soil moisture at the critical limit of water for plant growth. They described the use of 'long period curves of growth' in maintaining cane growth without cessation and the indications of the total potential cane lost during the periods when soil moisture fell below the wilting coefficient of the soil. By this procedure, which is now a routine practice at all the plantation estates of the Hawaiian Islands, great economy in the use of water has been effected.

Material and methods

Growth in length. The procedure of selecting shoots, technique of growth measurement, posting of growth measurement data and dissection of stools have already been described by the author [1944] in another connection, wherein a part of the co-ordinated study conducted to evaluate growth characters of varieties and determination of the irrigation requirements of varieties and the influence of different irrigation intervals on the juice quality and yield of cane at harvest have been reported. Ten mother shoots were selected at random, two in each row of the net experimental plot, and growth measurements, taken at regular intervals, were recorded over the entire life cycle of the crop. The results were so tabulated as to obtain cumulative growth in length curves and exponential height

growth curves, for working out the growth constants. i.e. initial rapidity of growth values (A constant), efficiency indices of plant growth, mean daily growth rate, etc.

Underground branching. Barber [1919] has described in detail the procedure of study of underground branching in canes. His procedure was adopted for varietal studies in the two trials conducted in the year 1941-1942. Ten clumps, for each of the varieties, were examined at harvest.

These clumps had been under close study from the early time of their germination when they had been tagged. As shoots appeared they were serially numbered and deaths if any occurring were recorded at regular intervals. So that at the time of dissection the clump could be separately analysed for (*a*) cane forming shoots, which we have termed as mature shoots, (*b*) shoots not cane forming, named as immature shoots, (*c*) healthy shoots, that is those stalks which were unaffected by borers, white ants, etc. at any stage of their life and (*d*) diseased shoots which had been affected at some stage or the other by insects, diseases and other physiological causes. Of these healthy and diseased shoots both immature and mature shoots come under these sub-heads so that interactions could be worked out amongst varieties and any other of the above sub-groups.

The studies were very laborious and required dissection of the stools by the author himself; these, therefore, could not be repeated during the following season, when analysis of the data were carried out.

Millable cane characters. Each of the mature canes, from the various clumps, dissected for analysis, was weighed, its total length recorded and its girth at three mid-joints, i.e. top, middle and bottom joints was noted. Instead of the radial and medial thickness of joints as had been recorded by Barber [1915] girth measurements gave better values for the mean thickness of the joints. Ratios between mean total length of the canes and their mean thickness of joints were worked out and have been noted as cane module values. For instance in one case the cane module value was worked out as follows :—

Mean cane length $=188{\cdot}5\pm51{\cdot}18$ cm.
Mean cane girth $=6{\cdot}9\pm0{\cdot}87$ cm.
Therefore, mean thickness $=6{\cdot}9\times7/22=2{\cdot}196$ cm.
Hence, cane module $=188{\cdot}5/2{\cdot}196=85{\cdot}9$ or 86.

The figure 86 represents, in round numbers, the cane module value of the variety of which the results are given above and is in the nature of an index used by Barber [1918] to indicate group differences in the Indian canes of Sunnabile and Saretha groups. We have, however, recorded all these data with a view to differentiate millable cane characters amongst the varieties.

Procedure of analysis of the experimental data

Fitting of growth curves and testing significance. Blackman and others working with dry weights of plants have used the compound interest concept, whereas we have to deal with growth in length data so that according to Heath [1932] the formula to be used becomes

$$H= \qquad Ae^{bt}$$

where, A is the length attained by an initial time, H is the final length attained, b is the rate or an index of 'efficiency of the plant as a producer of new material', t is the time and e is the base of natural logarithm. With seed plants the original point indicated is the embryo weight. But with sugar cane where setts are planted no such well defined point is apparent. Therefore, the initial point in most cases was taken soon after the germination of the crop was completed. In a few cases the initial point was taken much later in view of unavoidable circumstances which necessitated postponing the studies for a time. For comparative results in the same year, as had been shown by Summerville [1944], it did not matter.

Correlation of growth A and b values. Correlation coefficient was determined between the inherent growth factor A and the ultimate yield of the varieties on the one hand and between the relative growth rates (b values) of the varieties and their mean sugar contents during the crushing season on the other and for doing so there is some justification, for the deductions obtained from the correlations have a sound physiological interpretation of the data. This has, however, been discussed in a later part of the text.

Mean daily growth rate. The average daily growth rates of the varieties were worked out by the formula log $e\ H_2$—log $e\ H_1/n'$, where H_2 is the final height, H_1 is the initial height and n' is the number of days from H_1 to H_2 [Afzal and Iyer, 1934]. The average daily growth rates of different varieties in the various trials were worked out for comparison against the efficiency index values (relative growth rates) of the varieties. The values of the coefficient of correlation between mean daily growth rates and the relative efficiency indices were also worked out.

EVALUATION OF THE PARAMETERS AND THEIR RELATIONSHIP TO THE VARIETAL PERFORMANCE

Physiological experiment—1940-1941 series. The work was begun in the year 1940 on a trial consisting of varieties Co290, Co281, Co331, Co205 and Co432. It was in the nature of a physiological experiment with widely divergent varietal material. These varieties were planted in four randomized blocks on a loam soil. During germination and up to the middle of April, the field was irrigated at ten days intervals. Later on irrigations were applied when the soil attained critical moisture limit for active cane growth of the crop. The interval was determined by the approach of the wilting coefficient of the soil within the first six inches of the soil which was noticed to cause a setback in the active cane growth of the crop.

Cumulative growth in length. The results of the cumulative growth in length of the varieties have been shown in Fig. 1. All the varieties had normal form of the sigmoid curves and had almost equal stand till about the 95th day after planting when differences in growth amongst the varieties began to manifest themselves more apparently. The point of inflection in the boom stage was noticed on 130th day. The grand growth period extended up to 180th day. The active growth was maintained for another month. From 210th day the curve of growth tended to run parallel to ordinate. Individually Co331 maintained somewhat higher rate of growth up to 195th day when the curve of absolute growth of Co290 outstripped it. Varieties Co205 and Co432 behaved identically. The former generally had a slightly higher rate of growth than the latter. The growth curve of Co281 was distinctly different from rest of the varieties. It occupied a mid-position up to 125th day when a lag in it began to appear. At harvest it had the lowest stand.

Exponential height growth curves. The calculated exponential height growth curves of the varieties are given in Table I below.

TABLE I

Exponential height growth curves

Variety	Number of observations	Equation $H=Ae^{bt}$	S.E. of b	Mean yield per acre in md.	Mean sucrose content juice (percentage)
Co205	55	$H=2{\cdot}179e^{0{\cdot}01677t}$	0·000780	637	11·22
Co281	55	$H=3{\cdot}589e^{0{\cdot}01782t}$	0·000947	384	13·30
Co290	55	$H=4{\cdot}137e^{0{\cdot}01799t}$	0·001029	524	11·40
Co432	55	$H=4{\cdot}481e^{0{\cdot}01594t}$	0·001218	706	8·44
Co331	55	$H=4{\cdot}575e^{0{\cdot}01652t}$	0·001015	784	10·76

The two parameters estimated are fairly clearly shown in the exponential height growth curves. The statistical comparison of b values showed that the efficiency index values of variety Co281, in order, was significantly greater than Co432, Co331 and Co205 at five per cent level of significance and that of Co290 at 10 per cent level of significance. Viswa Nath [1919] had shown that side by side with the elongation of the cane stem there occurs an accumulation of sugar in the cane joints. Physiologically, therefore, the relative growth rate should correspond to the sucrose content in the cane. The value of the coefficient of correlation between the efficiency indices of the varieties and their mean sucrose performance during the crushing season was, therefore, worked out. The value

$+0 \cdot 97$ ($>P=0 \cdot 01$) was observed to be highly significant. The importance of these results in the selection of varieties pertaining to the environment has been emphasised later in the text.

Early growth of the varieties does not appear to very much influence the yield of the varieties as the correlation between the parameter A and the yield values was observed as non-significant. The low value worked out was $+0 \cdot 28$ only.

The growth studies in the following year were extended to the medium-early and mid-season varietal trials.

MEDIUM-EARLY SERIES

The varieties planted in the medium-early series, now under review, were Co312 (Standard), Co281, Co313, Co299, Co427 and Co549. These varieties were selected on the basis of yield and sugar performance from the multiplication series at the close of 1940-1941. Variety Co312, which served as standard in the trial, in reality is a mid-season cane. This was included to see how far the medium-early canes were comparatively lower in acre yields and if the extra yield of sugar on cane, early in the season (mid-December), in the highest yielding medium-early variety could compensate for the loss in yield as compared to the standard in the trial. For the first two seasons the growth measurements were recorded on the plant crop of the varieties in the trial. In the final year the preceding year's trial was ratooned and growth measurements on the ratooned varieties were recorded.

Cumulative growth curves. A detailed study of cumulative growth curves of the varieties indicated some differences worth recording. In the first season of study, the formative period of the crop growth extended over 70 days. The mean growth made by varieties was about 19 cm. The boom stage lasted for 130 days and in this period the mean growth accumulated was 216 cm. In the senescent phase the accumulation was 50 cm. of the total growth made by then and this phase extended over a period of 45 days. In the next year the formative period covered 130 days in which period on the average all varieties accumulated about 18 cm. of growth. Correspondingly the boom stage was reduced to 90 days and in this period plants made up a stand of 139 cm. The senescent phase was short and consisted of 25 days only, in which period it accumulated 12 cm. of growth. The medium-early ratoon crop had a moderately long formative period of 110 days. During this period the plants accumulated 125 cm. Boom period lasted for 100 days and in this period the plants accumulated 125 cm. of growth. In the senescent phase of 70 days the plants accumulated 13 cm. of growth only. Thus a considerable variation in the lengths of formative, boom and senescent phases of growth of the crop is observed in different years. Besides it is noticed that an extended formative period is not of any special advantage. Increase in the length of the senescent phase also does not confer any benefit on the plants. From the results it is conceiveable that an extended boom period relatively proves to be of some advantage to the crop.

Individually varieties in the same year also showed differences of interest. Generally, Co427 maintained the highest level of cumulative growth throughout the life cycle of the crop. In the early formative stages Co312 slightly had a better stand than Co427. It is probably this very early start, coupled with greater tillering, that accounts for higher yield of Co312 as compared to Co427 in spite of the better growth of the latter in the grand growth period of the crop. Then we have another set of varieties, namely, Co549, Co299, Co281 and Co313, which had lesser accumulation in the formative period and a comparatively earlier decline of the curve in the senescent phase of the crop. All these varieties generally exhibited high sugar content. Highest early maturity was shown by variety Co281 which had the maximum lag in the tail end of the curve of cumulative growth in length. All the curves of cumulative growth in length were of normal sigmoid type.

In 1942-1943 the curve of cumulative growth in length of variety Co312 in the initial stages had distinctly a better stand than others. At the point of inflection when varieties entered the grand growth period, in comparison to Co313 and Co299, the curve of Co312 began to indicate a lag. The differences widened as the crop entered upon its maturition stage. This lag was more pronounced in the curve of Co427 than that of Co312. Varieties Co299 and Co549 indicated an identical behaviour through the formative, grand growth and senescent phases of the crop. Co313 had a lower start in the formative period; in the boom period its curve of cumulative growth in length crossed over others and stood the highest at the close of the maturity period.

The curve of cumulative growth in length of variety Co427 in the crop season 1943-1944 (ratooned crop) through the formative, grand growth and senescent phases had the highest stand. Thus it could maintain a higher growth level than Co281 and Co312 till the sigmoid curves sloped down to run parallel to the ordinate, i.e. when the crop had entered upon its senescent phase. Varieties Co299 and Co549 started with a low absolute increase in height and growth and accumulated less and less of height as time elapsed.

Collectively the varieties generally showed less growth during the months of April, May and June in 1942-1943 as compared to the year 1941-1942. In both these years varieties compared were of plant crop. During July to September the growth in the two years was almost comparable but was again smaller in the latter year in the months of October and November than in the crop season of 1941-1942. Amongst the varieties, Co427 generally in all the months exhibited the depressing effect of the environment more than other varieties. Variety Co281 indicated relatively greater lag in the months of October and November than in other months, although in the perceding two months, i.e. in August and September, contrary to the general trend of the varieties, the growth accumulated was more in 1942-1943 than in the year 1941-1942. Variety Co313 exhibited such a feature in the months of July and August.

Exponential height growth curves. The results of the calculated exponential height growth curves of the varieties in the medium-early series for the three seasons are given in Table II.

TABLE II

Exponential height growth curves

Variety	Equation $H=Ae^{bt}$		
	1941-1942 (Plant crop)	1942-1943 (Plant crop)	1943-1944 (Ratoon crop)
Co312 (St.) . .	$H=12{\cdot}34e^{0{\cdot}01435t}$	$H=5{\cdot}68e^{0{\cdot}01284t}$	$H=12{\cdot}55e^{0{\cdot}01034t}$
Co427 . . .	$H=11{\cdot}10e^{0{\cdot}01556t}$	$H=2{\cdot}50e^{0{\cdot}01653t}$	$H=17{\cdot}53e^{0{\cdot}01076t}$
Co549 . . .	$H=9{\cdot}42e^{0{\cdot}01544t}$	$H=2{\cdot}03e^{0{\cdot}01820t}$	$H=9{\cdot}74e^{0{\cdot}01104t}$
Co299 . . .	$H=8{\cdot}63e^{0{\cdot}01595t}$	$H=1{\cdot}82e^{0{\cdot}01842t}$	$H=9{\cdot}60e^{0{\cdot}01049t}$
Co313 . . .	$H=7{\cdot}53e^{0{\cdot}01643t}$	$H=2{\cdot}35e^{0{\cdot}01786t}$	$H=8{\cdot}69e^{0{\cdot}01247t}$
Co281 . . .	$H=6{\cdot}44e^{0{\cdot}01785t}$	$H=1{\cdot}97e^{0{\cdot}01848t}$	$H=6{\cdot}68e^{0{\cdot}01345t}$

In the crop season 1941-1942 varieties Co312 and Co427 had comparatively very rapid growth in the initial stages, which period corresponded to the formative stage of the varieties. Varieties Co549 and Co299 had a medium rapid initial growth and varieties Co313 and Co281 took the slowest initial start.

In relative growth rate, i.e. with regard to b values the order of varieties was almost reversed. Variety Co312 had the least relative growth rate ; Co427, in spite of its high initial start, correspondingly had a fairly high relative growth rate of elongation, which is comparable to those of varieties Co549 and Co299, but it is definitely less than those of varieties Co313 and Co281. Statistically the relative growth rate of Co281 was significantly greater than that of Co427, Co549 and Co312, the differences amongst Co281, Co299 and Co313 being not significant. Again, statistically the values of Co313, Co299 and Co427 were the same at 5 per cent level of significance. But all the varieties, namely, Co281, Co313, Co299 and Co427, had significantly higher growth rate values than Co312, the difference between the values of varieties Co312 and Co549 being not significant.

It is evident from a comparison of the equations for the different varieties in the two seasons, i.e. 1941-1942 and 1942-1943, that A values generally were lower and b values higher in the latter than in the former season. In fact A values of varieties Co299, Co427 and Co549 were much more depressed than those of the varieties Co313 and Co281. When the A values of the variety Co312 is taken as normal for the two seasons, a comparison of the values of other varieties is possible. This

is shown in Table III. The former three showed over 40 per cent depression compared to about 18 per cent in the latter two.

TABLE III

Relative values of parameter

Varieties	1941-1942		1942-1943		Percentage differences in two years in *A* values
	Parameter *A* values	Percentage of maximum	Parameter *A* values	Percentage of maximum	
Co312	12·34	100·0	5·68	100·0	..
Co427	11·10	90·0	2·50	44·0	46·0
Co549	9·42	76·3	2·03	35·7	40·6
Co299	8·63	80·0	1·82	32·5	48·5
Co313	7·53	61·0	2·35	41·3	19·7
Co281	6·44	52·2	1·97	34·6	17·6

In a similar manner the differences amongst the *b* values of the varieties in the two seasons are shown in Table IV; percentage differences in the two seasons are shown in last column of the table. The differences were more appreciable in varieties Co299, Co549 and Co312 than in others. These

TABLE IV

Relative values of parameter b

Varieties	1941-1942		1942-1943		Percentage differences in two seasons
	Parameter *b* values	Percentage of maximum	Parameter *b* values	Percentage of maximum	
Co281	0·01785	100·0	0·01848	100·0	..
Co313	0·01643	92·0	0·01786	96·6	—4·6
Co299	0·01595	89·3	0·01842	99·6	—10·3
Co427	0·01556	87·2	0·01653	89·4	—2·2
Co549	0·01544	86·5	0·01829	98·9	—12·4
Co312	0·01435	80·4	0·01284	69·4	+11·0

differences in both the parameters may be attributed to the edaphic and weather differences, the effect of which has been discussed later.

The data for the worked-out exponential height growth curves for the ratoon crop of 1943-1944 season have also been summarized in Table V. It will be noticed that variety Co427 had the highest *A* value; the next high value was that of variety Co312, varieties Co549, Co299 and Co313 had almost equal values, while Co281 had the lowest value of all the varieties in the trial. In respect of relative growth rate or *b* values Co281 had the highest value, the next higher value was that of Co313. The values in other five varieties were not appreciably different one from the other.

Table V

Correlation coefficients

Parameter A=A ; mean yield per acre in md.=B ; parameter b=C ; mean sucrose percentage in juice=D

Variety	Growth constants, yield and sucrose data											
	1941-1942				1942-1943				1943-1944			
	A	B	C	D	A	B	C	D	A	B	C	D
Co312 . . .	12·34	767	0·01435	10·23	5·68	552	0·01284	10·99	12·55	806	0·01034	12·05
Co427 . . .	11·10	637	0·01556	11·35	2·50	430	0·01653	12·35	17·53	741	0·01076	13·02
Co549 . . .	9·42	453	0·01544	12·06	2·03	400	0·01829	12·61	9·74	641	0·01104	14·37
Co299 . . .	8·63	499	0·01595	12·32	1·82	432	0·01842	12·66	9·60	596	0·01049	13·29
Co318 . . .	7·53	656	0·01643	11·96	2·35	449	0·01786	13·11	8·69	716	0·01247	13·34
Co281 . . .	6·44	375	0·01785	13·31	1·97	321	0·01848	13·56	6·68	574	0·01345	14·53
Coefficient of correlation . .	+0·326		+0·926		+0·818		+0·915		+0·556		+0·711	
Significant at .	..		P=0·01		P=0·05		P=0·01		..		P=0·10	

Correlations were worked out between A values of varieties and their mean values for the yields of all the replications of the trial on the one hand and between the relative growth rate values of the varieties and their mean sucrose percentage in juice over the entire crushing season. The summarized data have been presented in Table V. The value of the correlation coefficient between the mean yield of the varieties and their initial rapidity of growth values was low in the year 1941-1942 ; it was significant at 5 per cent level in the year 1942-1943 and moderate in the crop season 1943-1944, but not significant even at 10 per cent level of significance. Correlation coefficients between the relative growth rates of the varieties and their mean sucrose percentage in juice were significant in all the three years. In the first two seasons the values were very high while in the third season, i.e. in 1943-1944 it was significant at 10 per cent level only. The results thus indicate that the yield is influenced by the initial rapidity of growth and the accumulation of sugar is closely bound up with the relative rates of growth of the varieties. The significance of these results has been discussed later.

Mid-season series

In the mid-season series the varieties included were Co290 (St.), Co312, Co331, Co419, Co438, Co451 and Co534. Growth in length record were obtained for three seasons, namely, 1941-1942, 1942-1943 and 1943-1944. In the crop season 1942-1943 the preceding year's trial was ratooned and experimental record was obtained on the ratoon crop also, to compare the performance of the varieties with the plant crop of the same season.

Cumulative growth in length. Cumulative growth curves of varieties, drawn to figure the differences in the various periods of growth in the life cycle of the plants, in the crop season 1941-1942, indicated that varieties Co290, Co312 and Co438 behaved fairly identically and ran a parallel course through the three phases of growth ; variety Co534 maintained distinctly a low level of growth in the formative, grand growth and senescent phases of the crop life ; and the rest of the three varieties, namely, Co331, Co419 and Co451 showed different performance in the various phases. Variety Co331 with a very high growth level in the formative period indicated a lag in the latter two phases,

Variety Co451 kept up a high growth level only up to the earlier part of the boom period, later on a lag was evident but it was less pronounced than in Co331. Variety Co419 had a low growth level in the formative and up to mid-boom stage, after mid-boom stage there was a rise in the cumulative growth curve of the variety.

Under the environmental conditions prevailing in the crop season 1942-1943 variety Co331 in the plant crop series had accumulated the largest amount of growth. It took a start in the formative period and maintained it up. Variety Co290 though had some lag in the early growth stage stole a march over other varieties beyond the point of inflection. Varieties Co419, Co438 and Co534 had a tardy start in the initial stages. During the mid-boom stage its growth level was enhanced and it had greater cumulative growth in length than the remaining two varieties, namely, Co312 and Co451, by the close of the senescent phase, which, in spite of the good start in the formative period, showed a lag in the boom and senescent phases of growth of the plants. Such a lag in variety Co312 was apparent in the medium-early series of this year also.

In the ratoon crop the cumulative growth in length of varieties Co451 and Co534 was superior than that of the plant crop. Variety Co331 had as good accumulation of growth in the ratoon as in the plant crop of that season. Co534 when ratooned ran a course very close to Co331 over all the phases of crop growth, while the curve of growth of variety Co451 slightly deviated away from Co331 when the sigmoid curve during the senescent phase tended to run parallel to the ordinate. Similarly the cumulative curves of growth of varieties Co419 and Co438 ran a parallel course through the three phases of growth, but their rate of increment of growth accumulation was smaller than that of Co331, Co534 and Co451. Varieties Co290 and Co312 maintained a lead over Co419 and Co438 till the mid-boom stage when Co312 showed a rapid falling off in growth while Co290 kept on close to the growth curves of varieties Co419 and Co438. The cumulative effect of growth was more apparent towards the maturation or senescent phase of the crop.

In the year 1943-1944 curves of cumulative growth in length of varieties Co331, Co451, Co290 and Co312 with slight variations ran a parallel course through all the phases of cane growth. In the preceding year the environment was not so suitable for rapid accumulation of growth in the case of Co290 and Co312-as in the year under report. The remaining varieties that could be grouped together were Co438, Co419 and Co534. The curves of growth of these varieties tended to deflect away from the course of the former group from the mid-boom stage onwards as the curves tended to run parallel to the ordinate.

Scanning over the mean values of all the varieties in the different years one finds that the formative period in the year 1941-1942 lasted for 45 days only and in this period the mean accumulation of growth was 13 cm. The boom period extended over 150 days in which plants accumulated 217 cm. In the senescent phase 22 cm. of growth was added within 50 days. Compared to this in the following year plant crop had formative period extended by another 35 days in which extra growth accumulated was only 5 cm. Proportionately, thus, the boom period was reduced by a corresponding period and lasted for 100 days only. In this span of life the growth accumulated was 146 cm. In view of the short grand growth period senescent phase was prolonged by another 15 days, but the environment being not very favourable the growth accumulated was 13 cm. only compared to 22 cm. in the preceding year. The ratoon crop had an extended period of crop growth by about 40 days and this helped in greater accumulation of growth, the comparative accumulated lengths in plant and ratoon crops being 146 and 221 cm. respectively. The 1943-1944 series had fairly long formative period with small growth accumulation. The boom period lasted over a short period of 110 days when plants accumulated 148 cm. It is in the senescent phase that the plants accumulated rather more than in the preceding year. Within a period of 50 days the accumulation was 70 cm, as against 65 days and 13 cm, in the crop season 1942-1943. These interesting differences in crop growth have their significance in explaining some of the peculiarities in varieties. These have been pointed out later on.

Exponential height growth curves. In Table VI are given the results of worked out exponential height growth curves for the three seasons in which studies were carried out. The data for the ratoon crop of the year 1942-1943 is also included in Table VI for comparison with the plant crop of the same year.

TABLE VI

Exponential height growth curves

Varieties	Equation—$H=Ae^{bt}$			
	1941-1942 (Plant crop)	1942-1943 (Plant crop)	1942-1943 (Ratoon crop)	1943-1944 (Plant crop)
Co331	$H=11{\cdot}52e^{0{\cdot}01472t}$	$H=7{\cdot}56e^{0{\cdot}01744t}$	$H=5{\cdot}00e^{0{\cdot}01532t}$	$H=10{\cdot}13e^{0{\cdot}0134t}$
Co312	$H=9{\cdot}98e^{0{\cdot}01598t}$	$H=5{\cdot}83e^{0{\cdot}01677t}$	$H=4{\cdot}19e^{0{\cdot}01474t}$	$H=11{\cdot}06e^{0{\cdot}01323t}$
Co290 (St.)	$H=9{\cdot}36e^{0{\cdot}01687t}$	$H=6{\cdot}91e^{0{\cdot}01686t}$	$H=5{\cdot}96e^{0{\cdot}01396t}$	$H=8{\cdot}03e^{0{\cdot}01499t}$
Co438	$H=8{\cdot}34e^{0{\cdot}01739t}$	$H=5{\cdot}46e^{0{\cdot}01742t}$	$H=3{\cdot}04e^{0{\cdot}01639t}$	$H=7{\cdot}75e^{0{\cdot}01454t}$
Co451	$H=7{\cdot}62e^{0{\cdot}01759t}$	$H=4{\cdot}53e^{0{\cdot}01537t}$	$H=0{\cdot}68e^{0{\cdot}02393t}$	$H=8{\cdot}96e^{0{\cdot}01455t}$
Co419	$H=6{\cdot}39e^{0{\cdot}01809t}$	$H=4{\cdot}53e^{0{\cdot}01885t}$	$H=3{\cdot}18e^{0{\cdot}01639t}$	$H=8{\cdot}46e^{0.01399t}$
Co534	$H=4{\cdot}34e^{0{\cdot}01824t}$	$H=3{\cdot}76e^{0{\cdot}01848t}$	$H=1{\cdot}25e^{0{\cdot}02181t}$	$H=2{\cdot}12e^{0{\cdot}02182t}$

A perusal of the plant crop data for the season 1941-1942 revealed wide variations in the two parameters determined from the curves. Parameter A was the highest in Co331, indicating the highest growth rate in the initial stages of the crop. Value A of the variety Co534 was the least. Evidently it possessed the lowest initial potential of growth of all the varieties in the trial. The other varieties had A values in between the A values of these two varieties. Statistically Co331 had significantly higher A value than that of varieties Co438, Co451, Co419 and Co534, those of Co312 and Co290, equal between themselves, were greater than Co419 and Co534, and those of Co438 and Co451 greater than Co534 only.

The parameter A values of the various varieties, in the crop season 1942-1943, were of a different order than in 1941-1942. For instance Co290 and Co451 had higher value than Co312. Statistically critical difference at $P=0{\cdot}05$ worked out to 1·198 cm. Thus A value of Co331 was greater than that of Co312, Co438, Co419 and Co534, of Co290 was greater than that of Co438, Co419 and Co534, of Co451 and Co312 were greater than that of Co419 and Co534; Co438 alone had a significantly higher A value than that of Co534.

In the final year the crop plant of the mid-season series indicated a slightly different order of its A values from those in each of the two preceding years. The A value of Co534 was exceptionally low as compared to A values of the other varieties. The critical difference for the series was 1·087 cm. at $P=0{\cdot}05$. Between themselves Co312 and Co331 statistically showed non-significant difference while they had significantly greater A values than rest of the varieties. Varieties Co451, Co419, Co290 and Co438 had significantly higher A values than Co534.

A comparison of A values of the varieties, in the mid-season plant crop trial, in the three seasons, indicates that the parameter A values, without consideration of the individual variations, for the crop season 1942-1943 were generally lower than that of either 1941-1942 or 1943-1944. It is also noticed that the ratoon crop values of the initial growth in length in this year were further lower than the plant crop. This was so collectively for the trial as well as individually for every one of the varieties. Obviously environmental differences must have brought about these differences. On this point we have gone in some detail in the succeeding portion of the text.

Parameter b values in the crop season 1941-1942 showed significant differences amongst the varieties. Variety Co331 had a significantly lower value than that of Co534, Co419, Co451, Co438 and Co290, but statistically it was equal to that of Co312, which in turn also showed non-significant differences over that of the former five varieties.

In the crop season 1942-1943 the parameter b was the lowest in the case of Co451 and not Co331 which had higher value than that of the varieties Co312 and Co290. Statistically parameter b value of Co534 was significantly higher than that of Co451 and Co312 and that of Co419 higher than the value of Co451 alone. The differences amongst others were not significant.

The parameter b values of variety Co534, again, was the highest in the third year of study and showed a significant difference over all others. The lowest value was recorded for the variety Co312. The varieties Co290, Co438, Co451, Co419, Co331 and Co312 did not show significant differences amongst themselves.

A comparison of the *b* values of the plant crop as against the ratoon crop showed differences in some important respects. As plant crop Co451 had the lowest value, but as ratoon crop it had a fairly high *b* value. On the other hand Co419 as plant crop had a fairly high value but as ratoon crop its value was considerably reduced. Similar position was noticed in the case of Co290 and Co312.

Though the comparison of the parameter *A* and *b* values is important to assess the performance differences of the varieties in the various years, it is still more important to know how these figures are correlated to the yields or mean sugar values in the different seasons. A comparison is provided in Tables VII and VIII.

Table VII

Values of parameters A and acre yields

Parameter *A* value=A ; Mean yield per acre in md.=B

Varieties	1941-1942 Plant crop		1942-1943 Plant crop		1942-1943 Ratoon crop		1943-1944 Plant crop	
	A	B	A	B	A	B	A	B
Co331	11·52	1071	7·56	339	5·00	1012	10·13	368
Co312	9·98	944	5·83	457	4·19	744	11·06	515
Co290 (St.)	9·36	743	6·91	375	5·96	664	8·03	368
Co438	8·34	838	5·46	429	3·04	529	7·75	408
Co451	7·62	916	6·55	272	0·68	644	8·96	317
Co419	6·30	911	4·53	182	3·18	709	8·46	389
Co534	4·34	756	3·76	272	1·25	534	2·12	267
Coefficient of correlation	+0·41		+0·382		+0·534		+0·817 ($>P=0{\cdot}05$)	

The values of the correlation coefficients worked out between parameter *A* values and the mean yield values in all cases gave positive correlations. The value was significant for the crop season 1943-1944 only. In the case of medium-early varieties trial, a similar position was noticed which indicates that the initial rapidity of growth, although influencing the yield, is not the major factor determining the yields of the varieties.

The parameter *b* and mean sucrose values of the varieties in the different crop seasons are shown in Table VIII.

Table VIII

Values of parameter b and mean sucrose percentage in juice

Parameter *b* values=A ; Mean sucrose per cent in juice=B

Varieties	1941-1942 Plant crop		1942-1943 Plant crop		1942-1943 Ratoon crop		1943-1944 Plant crop	
	A	B	A	B	A	B	A	B
Co331	0·01472	8·84	0·01744	12·58	0·01532	12·18	0·01343	14·46
Co312	0·01598	9·23	0·01677	11·47	0·01474	12·37	0·01323	13·50
Co290 (St.)	0·01687	9·71	0·01686	12·12	0·01396	11·50	0·01499	13·77
Co438	0·01739	8·71	0·01742	11·73	0·01639	11·91	0·01454	14·83
Co451	0·01759	9·28	0·01537	12·04	0·01393	13·55	0·01455	14·46
Co419	0·01809	9·24	0·01885	12·62	0·01639	12·22	0·01399	13·77
Co534	0·01824	11·16	0·01948	13·11	0·02181	13·18	0·02182	15·71
Coefficient of correlation	+0·593		+0·713 ($>P=0{\cdot}10$)		+0·933 ($>P=0{\cdot}01$)		+0·785 ($>P=0{\cdot}10$)	

The values of the coefficients of correlation worked out between the relative growth rates of the varieties and their mean sucrose content values are shown in the last horizontal column of Table VIII. In 1941-1942 the value was not high enough to show significance even at P=0·10. For the ratoon crop in the year 1942-1943 the value was very highly significant. In the cases of plant crop in the two years, namely, 1942-1943 and 1943-1944, the correlation coefficients indicated were strong and the values were significant at P=0·10. Thus we observe that relative growth rate values have much to do with the accumulation of sugar in the juice. A high rate indicates greater accumulation and *vice versa*. Later on these results in conjunction with those of the medium-early series have been discussed.

RELATIONSHIP BETWEEN EFFICIENCY INDICES AND MEAN DAILY GROWTH RATES OF VARIETIES

From the above it is evident that efficiency indices are highly correlated to the mean sucrose percentage in the juice of the varieties. The values, as we know from the mathematical evaluation, also takes into account the mean daily growth rates of the varieties. Let us then find out if it is so in the case of sugar cane as has been shown by Afzal and Iyer [1934] in cotton. The data given in Table IX summarizes the results of comparison.

TABLE IX

Comparison of mean daily growth rate and relative growth rate

Crop season and nature of trial	Varieties	Initial measurement in cm.=H_1	Final measurement in cm.=H_2	Number of days H_1 to H_2	Mean growth rate	Efficiency indices	Value of r
1940-1941— Physiological series (Plant crop)	Co331	5·91	197·80	216	0·01623	0·01652	
	Co432	7·33	188·28	216	0·01501	0·01594	
	Co290	6·45	198·86	216	0·01587	0·01699	—0·016
	Co281	7·28	179·46	216	0·01484	0·01762	
	Co205	7·31	188·84	216	0·01493	0·01677	
1941-1942— Medium-early series (Plant crop)	Co312	18·11	227·38	192	0·01318	0·01436	
	Co427	16·90	236·08	192	0·01372	0·01556	
	Co549	17·21	215·76	192	0·01317	0·01544	+0·0301
	Co299	16·50	215·45	192	0·01338	0·01595	
	Co313	13·89	208·69	192	0·01419	0·01663	
	Co281	16·02	208·68	192	0·01337	0·01735	
1941-1942— Mid-season series (Plant crop)	Co331	11·28	244·06	217	0·01377	0·01472	
	Co312	8·24	265·64	217	0·01600	0·01598	
	Co290	10·39	235·26	217	0·01638	0·01687	
	Co438	8·77	261·43	217	0·01564	0·01739	+0·794
	Co451	6·46	237·32	217	0·01661	0·01759	
	Co419	6·83	232·66	217	0·01640	0·01811	
	Co534	4·90	224·32	217	0·01762	0·01824	
1942-1943— Medium-early series (Plant crop)	Co312	12·68	178·06	207	0·01129	0·01284	
	Co427	8·89	148·98	207	0·01362	0·01653	
	Co549	7·77	190·06	207	0·01559	0·01829	
	Co299	8·45	182·23	207	0·01484	0·01842	+0·981
	Co313	9·17	198·51	207	0·01485	0·01786	
	Co281	8·54	190·17	207	0·01499	0·01848	
1942-1943— Mid-season series (Plant crop)	Co331	14·02	228·48	198	0·01410	0·01744	
	Co312	11·52	155·71	198	0·01315	0·01677	
	Co290	11·22	189·43	198	0·01427	0·01686	
	Co438	11·15	170·47	198	0·01377	0·01742	+0·923
	Co451	13·15	155·77	198	0·01248	0·01537	
	Co419	7·05	178·54	198	0·01632	0·01885	
	Co534	7·57	167·89	198	0·01565	0·01948	

TABLE IX—*contd.*

Comparison of mean daily growth rate and relative growth rate—contd.

Crop season and nature of trial	Varieties	Initial measurement in cm. $=H_1$	Final measurement in cm. $=H_2$	Number of days H_1 to H_2	Mean growth rate	Efficiency indices	Value of r
1942-1943—							
Mid-season series (Ratoon crop)	Co331	15·45	283·00	199	0·01472	0·01532	
	Co312	12·12	211·39	199	0·01440	0·01474	
	Co290	16·78	236·07	199	0·01329	0·01396	
	Co438	15·10	239·67	199	0·01412	0·01639	+0·651
	Co451	10·11	264·69	199	0·01641	0·02393	
	Co419	12·13	243·55	199	0·01507	0·01639	
	Co534	17·42	289·75	199	0·01413	0·02181	
1943-1944—							
Medium-early series (Ratoon crop)	Co312	21·50	149·88	166	0·01170	0·01034	
	Co427	30·35	231·49	166	0·01224	0·01076	
	Co549	18·50	138·20	166	0·01225	0·01104	
	Co299	17·15	117·19	166	0·01158	0·01049	+0·850
	Co313	19·85	173·74	166	0·01307	0·01247	
	Co281	19·25	159·34	166	0·01273	0·01345	
1943-1944—							
Mid-season series (Plant crop)	Co331	14·40	178·76	162	0·01556	0·01343	
	Co312	14·20	175·94	162	0·01554	0·01323	
	Co290	16·55	176·58	162	0·01464	0·01499	
	Co438	11·75	158·86	162	0·01608	0·01454	+0·0209
	Co451	11·80	182·46	162	0·01690	0·01455	
	Co419	11·15	153·67	162	0·01619	0·01399	
	Co534	11·00	152·64	162	0·01623	0·02182	

Correlation coefficients between the two entities in each of the trials were separately worked out. In three cases out of eight the values were extremely low indicating that there did not exist any relationship between the relative growth rate and the mean daily growth rate of the crop in these trials. In one case, i.e. the ratoon crop of the mid-season series of 1942-1943, the correlation was found to be not significant, though the value indicated a relationship. In rest of the four cases the coefficients of correlation were significant. A correlation between the two was worked out for all the observations irrespective of the years, varieties or nature of the crop. A high correlation value was obtained ($r=0{\cdot}5766>P=0{\cdot}01$). This showed that mean daily growth rate for the four years' period on the whole was a good general index. Although this gross correlation between the two entities might lead one to assume that for all practical purposes the mean daily growth rate is a good measure of relative rate of growth of the crop, for it will reduce the labour of handling the data the individual correlation values point to the fact that the true measure of relative growth in plants is the one worked out by the concept of compound interest law as expounded by Blackman and daily growth rate, at best, is only a most probable indication of the performance of the variety in relation to others in the trial.

FORMATIVE GROWTH VALUES OF THE VARIETIES

In the growth of the plant it is not enough to study the growth in length alone, other factors must also be taken into account as distinct growth features of the varieties. Formative growth values of the varieties are some such factors of importance. These differences chiefly relate to the morphological characters specific to the different varieties in respect of the canes in the clump. Such characters have been studied in two trials, namely, mid-season and medium-early series.

Medium-early varieties. In Table X are given the underground branching data of the varieties in the medium-early trial. It will be noted that the data are complete for five varieties only. For unavoidable reasons all the stools of variety Co281 could not be dissected. Only five clumps of

this variety could be analysed. Therefore, the results for the five varieties are amenable to statistical analysis which is detailed in Table XI. It will be observed from Table X that varieties Co299, Co549, Co313 and Co281 in general showed more tillering than varieties Co312 and Co427. The former four varieties behave as early ripeners than the latter two. It may, however, be stated here that this fact refers to total tillering of the plants and not to the effective tillering which makes up the major portion of the crop. These differences were found significant. The analysis further revealed that varieties in general had a larger number of healthier stalks than diseased ones and taken together for the varieties the difference between the two was significant at $P=0{\cdot}05$, as is indicated by the significant value of the interaction between varieties and the healthiness of the stalks. Again diseased stalks less often matured than the healthy ones. This was particularly so of those that were damaged early in the season. It will be noticed that except the first order interaction between varieties and the mature versus immature stalks, the other interactions amongst all the three factors were significant.

Table X

Underground branching data—medium-early varieties

Varieties	Serial No.	Mature shoots								Immature shoots								Total shoots		
		Healthy				Diseased or damaged				Healthy				Diseased or damaged				Healthy	Diseased or damaged	Grand Total
		a	b	c	d&e	a	b	c	d&e	a	b	c	d&e	a	b	c	d&e			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Co 312	I	1	3	..	..	..	..	..	..	..	3	..	..	..	..	..	..	7	..	7
	II	1	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	..	4
	III	1	3	..	..	..	..	..	..	..	1	1	..	..	..	..	..	6	..	6
	IV	1	5	3	..	..	..	..	..	..	..	2	..	..	1	4	..	11	5	16
	V	1	1	..	..	..	..	..	..	..	..	..	..	..	2	..	..	2	2	4
	VI	1	4	..	..	..	1	..	..	..	3	..	..	..	..	..	..	8	1	9
	VII	1	2	..	..	..	2	..	..	..	..	..	..	..	1	..	..	3	3	6
	VIII	1	5	..	..	..	..	..	..	..	..	3	..	..	1	..	..	9	1	10
	IX	1	5	1	..	..	..	..	..	..	..	..	..	..	1	2	..	7	3	10
	X	1	3	..	..	..	..	..	..	..	..	..	..	..	3	4	..	4	7	11
Total		10	34	4	..	..	3	..	..	..	7	6	..	..	9	10	..	61	22	83
Co 299	I	1	5	3	..	..	..	..	..	..	..	..	..	..	2	3	..	9	5	14
	II	1	8	5	..	..	..	..	..	..	..	..	..	..	..	6	..	14	6	20
	III	1	3	..	..	..	..	..	..	..	..	..	..	..	2	..	..	4	2	6
	IV	1	4	3	..	..	..	..	..	..	..	..	..	..	6	2	..	8	8	16
	V	..	7	5	..	..	..	..	..	..	..	..	..	..	5	7	..	12	12	25
	VI	1	3	..	..	..	..	..	..	..	..	..	..	..	3	2	..	4	5	9
	VII	1	5	..	..	..	..	..	..	..	..	..	..	..	2	..	..	6	2	9
	VIII	1	2	5	..	..	..	..	..	..	..	..	..	..	4	12	1	8	17	25
	IX	1	4	1	..	..	2	1	..	..	..	..	..	..	3	3	..	6	5	11
	X	1	3	1	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..
Total		9	44	23	..	..	2	1	..	..	..	..	..	..	28	36	1	71	63	133

TABLE X—*contd.*

Underground branching data—medium-early varieties—contd.

Varieties	Serial No.	Mature shoots								Immature shoots								Total shoots		
		Healthy				Diseased or damaged				Healthy				Diseased or damaged				Healthy	Diseased or damaged	Grand Total
		a	b	c	d&e	a	b	c	d&e	a	b	c	d&e	a	b	c	d&e			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Co 281 . .	I	..	1	..	..	1	2	..	..	..	..	..	..	..	..	7	..	1	10	11
	II	1	4	..	..	..	1	..	..	..	..	..	..	..	..	2	..	5	3	8
	III	1	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	2	1	3
	IV	1	5	2	..	..	..	..	..	..	..	1	..	..	..	2	..	9	2	11
	V	..	3	1	..	..	..	..	..	..	..	..	..	1	2	8	..	4	11	15
Total .		3	13	4	..	1	4	..	..	..	..	1	..	1	2	19	..	21	27	48
Co 427 . .	I	1	5	..	..	..	..	..	..	..	..	3	..	..	1	..	..	9	1	10
	II	1	6	1	..	..	..	..	..	..	..	6	..	..	1	..	..	14	1	15
	III	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	2
	IV	1	3	1	..	..	..	..	..	..	..	1	..	..	1	..	..	6	1	7
	V	1	4	..	..	..	..	..	..	..	..	..	..	..	1	..	..	5	1	6
	VI	1	6	1	..	..	..	..	..	..	..	..	..	..	..	..	..	8	..	8
	VII	..	3	..	..	..	..	..	..	1	..	..	..	..	..	..	..	4	..	4
	VIII	..	4	..	..	1	..	..	..	..	1	..	..	..	2	..	..	5	3	8
	IX	1	5	2	..	..	..	..	..	..	2	..	..	..	1	..	..	10	1	11
	X	..	5	..	..	1	..	..	..	..	..	..	..	..	..	..	..	5	1	6
Total .		6	42	6	..	2	..	..	..	1	3	10	..	..	7	..	..	68	9	77
Co 313 . .	I	1	7	..	..	..	..	..	..	..	1	5	..	..	1	..	..	14	1	15
	II	1	5	1	..	..	..	..	..	..	1	7	..	1	..	..	..	15	..	15
	III	..	4	3	..	..	..	..	..	..	2	..	..	1	1	..	..	9	2	11
	IV	..	1	..	..	..	..	..	..	..	..	..	..	1	1	1	..	1	3	4
	V	1	5	4	..	..	..	..	..	..	2	2	..	..	..	1	..	14	1	15
	VI	1	4	1	..	..	..	..	..	..	1	..	..	..	..	1	..	7	1	8
	VII	1	6	..	..	..	..	..	..	..	..	3	..	..	1	2	..	10	3	13
	VIII	..	5	..	..	..	..	..	..	..	..	2	..	1	3	..	..	7	4	11
	IX	1	3	3	..	..	..	..	..	..	..	1	..	..	4	2	..	8	6	14
	X	..	3	1	..	..	..	..	..	..	..	..	..	..	..	9	..	4	9	13
Total .		6	43	13	..	..	..	..	..	..	7	20	..	3	11	16	..	89	30	119
Co 549 . .	I	1	5	6	..	..	..	..	..	..	..	..	2	..	1	..	..	14	1	15
	II	1	3	2	..	..	1	..	..	..	..	..	..	..	1	1	..	6	3	9
	III	1	2	..	..	..	..	..	..	..	..	..	..	..	1	..	..	3	1	4
	IV	..	3	2	1	1	1	..	..	..	..	..	..	..	3	..	..	6	5	11
	V	..	5	3	..	..	..	..	..	..	..	2	2	..	2	..	..	12	2	14
	VI	1	6	6	..	..	..	..	..	..	..	1	..	..	8	3	..	14	11	25
	VII	1	6	2	..	..	1	..	..	..	..	..	..	..	2	2	..	9	5	14
	VIII	1	3	2	..	..	..	..	..	..	..	..	..	..	..	2	..	6	2	28
	IX	..	4	3	..	1	..	..	..	..	..	..	..	..	..	2	..	7	3	10
	X	1	6	..	..	..	..	..	..	..	..	..	..	..	2	2	..	7	4	11
Total .		7	43	26	1	2	3	..	..	..	..	3	4	..	20	12	..	84	37	121

TABLE XI

Analysis of variance

Underground tillering data—medium-early varieties

Due to	D.F.	Sum of squares	Mean variance	V_1/V_2
Blocks	9	50·62	5·62	..
Varieties (V)	4	79·22	19·81	6·42**
Maturity of stalks (M)	1	67·28	67·28	21·82**
Healthiness of stalks (H)	1	224·42	224·42	72·88
Interactions :—				
V X M	4	24·72	6·03	1·96
V X H	4	44·18	11·04	3·58*
M X H	1	784·04	784·08	254·28**
V X M X H	4	432·82	108·21	35·09**
Residual error	171	527·28	3·08	

Standard error=$\pm$1·755 *Indicates significance at 5 per cent **Indicates significance at 1 per cent

Mid-season varieties. A perusal of Table XII will show some broad outstanding facts. For instance the major portion of the crop was formed of the 'b' shoots together with 'c' shoots in a few cases. Again 'c' shoots were the very shoots of which a large proportion remained immature because of the attack of pests, diseases and other physiological causes. Larger was the production of these two types of shoots, greater was the proportionate mortality in the varieties. Next, the varieties such as Co331, Co419 and Co451, possessing high yielding power, did not necessarily have a larger number of total tillers produced by the plants, other factors contributed potently to increase the yield, e.g. high germinability of varieties, thickness of stalks, etc. From the table of analysis of variance (Table XIII) it would be observed that the varieties differed widely in their underground branching. The varieties Co290 and Co312 had developed significantly greater number of underground branches than rest of the varieties. Again the varieties Co438, Co534 and Co451 had significantly a larger number of shoots than either Co331 or Co419. Secondly in general, the number

TABLE XII

Underground branching data—Mid-season series

Variety	Serial No.	Mature shoots								Immature shoots								Total shoots		
		Healthy				Diseased or damaged				Healthy				Diseased or damaged				Healthy	Diseased or damaged	Grand Total
		a	b	c	d&e	a	b	c	d&e	a	b	c	d&e	a	b	c	d&e			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Co 290	I	..	6	2	..	..	..	..	..	..	1	1	..	1	..	..	..	10	1	11
	II	..	2	11	3	..	..	..	..	..	..	..	..	..	2	3	6	16	11	27
	III	1	4	7	3	..	..	1	..	..	..	..	..	..	1	5	5	15	12	27
	IV	1	2	5	3	..	..	..	..	..	..	..	1	..	..	2	..	12	2	14
	V	1	8	3	..	..	..	..	..	..	..	..	..	..	1	8	1	12	10	22
	VI	1	2	12	5	..	..	..	8	..	..	..	..	..	1	4	..	20	13	33
	VII	1	7	6	..	..	..	..	..	..	..	1	..	..	1	..	..	15	1	16
	VIII	1	5	2	..	..	..	..	..	..	..	..	..	..	..	2	..	8	2	10
	IX	1	3	3	..	..	..	..	..	..	..	..	..	..	1	..	5	7	6	13

TABLE XII—*contd.*

Underground branching data—Mid-season series—contd.

Variety	Serial No.	Mature shoots								Immature shoots								Total shoots		
		Healthy				Diseased or damaged				Healthy				Diseased or damaged				Healthy	Diseased or damaged	Grand Total
		a	b	c	d & e	a	b	c	d & e	a	b	c	d & e	a	b	c	d & e			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Co 312 . .	I	1	2	5	..	..	..	..		..	..	..	..	..	4	1	2	8	7	15
	II	..	5	10	5	..	..	..	..	..	..	..	5	..	..	9	7	25	16	41
	III	1	6	2	..	..	..	..	..	..	..	..	3	1	6	..	..	12	7	19
	IV	1	6	9	..	..	..	..	..	..	..	4	2	..	1	1	1	22	3	25
	V	1	8	4	..	..	..	..	..	..	..	2	..	..	..	1	..	15	1	16
	VI	1	7	3	..	..	..	..	..	..	..	..	..	..	1	2	2	11	5	16
	VII	1	3	1	..	..	..	..	..	..	..	..	..	..	..	2	..	5	2	7
	VIII	1	3	2	..	..	..	..	..	..	..	..	..	..	1	4	1	6	6	12
	IX	1	8	3	2	..	..	..	..	..	..	3	..	..	1	5	..	17	6	23
Co 331 . .	I	1	1	..	..	..	..	..	..	..	..	2	..	..	1	..	..	2	1	3
	II	1	2	..	..		..	..	..	..	..	3	..	..	2	..	..	6	2	8
	III	1	3	..	..	..	..	..	..	..	..	..	..	..	1	..	..	4	1	5
	IV	1	2	..	..	..		..	..	..	..	..	..	..	4	3	..	3	7	10
	V	..	3	..	..	1	..	..	..	..	..	..	..	..	3	..	..	3	4	7
	VI	1	3	..	..	..	1	..	..	..	..	..	..	..	2	3	..	4	6	10
	VII	1	3	..	..	..	..	..	..	..	..	..	..	..	3	3	..	4	6	10
	VIII	1	3	1	..	..	..	..	..	..	..	..	2	..	..	4	..	7	4	11
	IX	1	2	..	..	..	..	..	..	..	..	..	..	..	3	..	..	3	3	6
Co 419 . .	I	1	2	..	..	..	..	..	..	..	..	..	..	..	1	..	..	3	1	4
	II	1	2	..	..	..	..	..	..	..	..	..	..	..	2	..	..	3	2	5
	III	..	3	..	..	..	..	..	..	..	..	..	..	1	3	..	..	3	4	7
	IV	..	3	1	..	1	..	..	..	..	..	..	..	..	2	2	..	4	5	9
	V	1	1	1	..	..	..	..	..	..	..	..	..	..	..	3	..	3	3	6
	VI	1	1	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	2	3
	VII	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	1	2
	VIII	..	3	4	..	..	..	..	..	..	..	..	..	1	1	2	..	7	4	11
	IX	1	3	..	..	..	..	..	..	..	..	..	..	..	..	2	..	4	2	6
Co 438 . .	I	1	6	7	1	..	..	..	..	..	..	..	..	..	2	2	1	15	5	20
	II	1	10	2	..	..	..	..	..	..	..	..	..	..	2	4	..	13	6	19
	III	..	3	3	..	..	..	..	..	..	..		..	..	4	2	..	6	6	12
	IV	..	6	4	..	..	..	..	..	..	..	..	..	..	3	1	..	10	4	14
	V	..	3	2	..	..	..	..	..	..	..	..	..	..	4	3	..	5	7	12
	VI	..	2	5	1	..	..	..	..	..	..	..	..	..	1	9	5	8	15	23
	VII	1	6	2	..	..	..	..	..	..	..	..	..	..	2	..	..	9	2	11
	VIII	1	9	7	1	..	..	..	..	..	..	..	..	..	1	3	2	18	6	24
	IX	1	4	2	..	..	1	..	..	..	..	..	..	..	6	1	..	7	8	15

TABLE XII—*concld.*

Underground branching data—Mid-season series—concld.

Variety	Serial No.	Mature shoots								Immature shoots								Total shoots		
		Healthy				Diseased or damaged				Healthy				Diseased or damaged				Healthy	Diseased or damaged	Grand Total
		a	b	c	d & e	a	b	c	d & e	a	b	c	d & e	a	b	c	d & e			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Co 451 . .	I	1	7	1	..	..	..	..	..	..	..	..	..	..	4	3	..	9	7	16
	II	1	5	..	..	..	..	2	..	..	..	..	..	..	..	5	..	6	7	13
	III	1	2	..	..	..	..	2	..	..	..	..	..	..	4	2	..	3	8	11
	IV	1	4	1	..	..	..	..	..	..	..	..	..	..	2	5	1	6	8	14
	V	1	3	1	..	..	1	..	..	..	3	..	..	..	6	6	..	8	13	21
	VI	1	3	1	..	..	..	..	..	..	..	..	..	..	2	5	..	5	7	12
	VII	1	4	..	..	..	..	..	..	..	..	..	..	..	..	8	..	5	8	13
	VIII	1	1	..	..	..	..	2	1	..	2	1	..	..	3	2	1	5	9	14
	IX	1	3	..	..	..	..	..	..	..	..	..	..	..	4	6	..	4	10	14
Co 534 . .	I	1	7	4	..	1	..	..	..	..	6	..	..	..	..	10	..	19	11	30
	II	..	3	1	1	2	..	..	..	..	..	..	..	2	3	2	..	4	8	12
	III	..	5	5	1	1	..	..	..	..	..	..	..	..	..	4	..	10	6	16
	IV	1	3	6	..	..	..	..	..	6	..	..	..	..	4	1	4	16	9	25
	V	1	4	2	..	..	..	..	..	..	..	..	..	..	4	5	..	7	9	16
	VI	1	4	3	..	..	..	..	..	..	..	..	..	..	3	7	..	8	10	18
	VII	1	3	1	..	..	..	..	..	..	4	..	..	..	4	4	..	9	8	17
	VIII	1	2	..	..	..	..	..	..	..	..	..	..	..	1	..	..	3	1	4
	IX	1	3	2	..	..	..	..	..	..	..	..	..	..	2	2	..	6	4	10

TABLE XIII

Analysis of variance

Underground tillering data—Mid-season series

Due to	D.F.	Sum of squares	Mean of variance	V_1/V_2
Blocks	8	68·58	8·57	..
Varieties (V)	6	389·28	64·88	9·92**
Maturity of stalks (M)	1	47·78	47·78	7·32**
Healthiness of stalks (H)	1	96·57	96·57	14·76**
Interactions :—				
V X H	6	177·88	29·65	4·53*
M X V	6	158·17	26·36	4·03*
M X H	1	2198·58	2198·58	335·99**
H X M X V	6	277·97	46·33	7·08**
Residual error	216	1412·64	6·54	

Standard error=±2·55 *Indicates significance at 5 per cent **Indicates significance at 1 per cent

of mature stalks was significantly larger than immature stalks. Thirdly, healthy stalks were significantly greater than the stalks which remained undeveloped due to diseases, pests or physiological causes. Fourthly, interaction between varieties and mature versus immature stalks was significant indicating that though varieties in general had a larger number of mature stalks than immature stalks, the varieties Co331, Co451 and Co534, differed from this general behaviour. They had slightly larger number of immature stalks than mature stalks. Fifthly, the interaction—mature versus

immature and healthy versus diseased stalks—was very highly significant. Matured stalks had a very high percentage of healthy stalks while in the immature stalks the number of diseased canes were proportionately high. Lastly, the second order interaction—varieties X mature versus immature X healthy versus diseased stalks—was also significant.

MILLABLE CANE VALUES OF VARIETIES

The mature stalks in the underground branching series were measured separately in both the trials, namely, medium-early and mid-season series. The data are given in Table XIV.

TABLE XIV

Millable cane values: (A—Medium-early series ; B -Mid-season series)

Series	Varieties	Mean cane weight in cm.	Mean cane length in cm.	Weight per unit length in cm.	Mean cane girth in cm.	Cane module value
A Series	Co312	581·7±85·4	188·5±51·2	3·09	6·9±0·87	86
	Co281	439·2±135·4	135·7±118·9	3·24	6·1±2·82	70
	Co299	524·0±160·3	184·3±36·5	2·84	5·4±1·66	107
	Co313	580·7±234·5	165·1±47·8	3·51	6·1±2·56	84
	Co427	732·9±237·4	202·3±86·9	3·62	7·8±0·22	82
	Co549	510·9±248·2	180·0±57·9	2·84	4·5±0·96	125
B Series	Co290	590·0±98·2	158·9±72·2	3·72	7·2±1·30	70
	Co312	631·6±257·5	172·2±73·6	3·66	7·0±1·32	78
	Co331	669·4±305·3	185·9±51·1	3·61	7·4±1·03	80
	Co419	1196·0±322·7	214·4±78·5	5·58	8·4±1·50	81
	Co438	601·7±238·5	186·7±50·2	3·22	6·4±0·90	93
	Co451	635·4±347·0	200·3±62·1	3·17	6·3±1·30	101
	Co534	613·0±292·2	166·2±42·0	3·69	6·8±1·80	78

It will be noted that varieties, in general, showed wide variations in the weight of the stalks, as is indicated by the high level of variation shown by them. Mean stalk length of varieties amongst themselves also exhibited conspicuous differences. In mean cane length of stalks the varieties individually showed as high a degree of variation as in cane stalk weight. Variety Co281 particularly had a remarkable variation in this respect. The range of variation in the medium-early varieties between minimum stalk length of Co281 and the maximum stalk length of the variety Co427 was 66·6 cm. In the mid-season series such a variation in the cane length amongst the varieties was 55·5 cm. Similar variation was noticed in mean cane girth of varieties in both the varietal series.

In the last column of Table XIV are given the cane module values for the varieties. The variation in the cane module values is as high as in the other millable cane characters of the varieties. One thing more is evident—the cane module values for a ten months crop of Sunnabile or Saretha group canes at Coimbatore were higher than crop of the same age in this province, although these groups are definitely less vigorous than the Co-cane [Barber, 1918] varieties.

In both the trials the standard cane variety was Co312. In the mid-season trial the weight per unit length of cane was higher than in the medium-early series. Now medium-early experiment was planted on light loam soil and was cropped in *Shaftal* (*Trifolium rasupinatum*) so that the land received no preliminary cultivation. The crop had an average stand. On the other hand, mid-season trial had been planted on well manured land which had received good cultivation. It appears probable that, as a consequence of this, a higher weight per unit length was obtained in the mid-season series as compared to the medium-early series. This point has been mentioned as a preliminary observation which requires confirmation by extensive study.

SIGNIFICANCE OF RESULTS

In the preceding text we have presented results of growth measurements of varieties in trials conducted during the years 1940 to 1944. For each of the varietal trials growth data have been presented as (a) cummulative growth in length, to indicate differences in the absolute growth of the

varieties and (b) exponential height growth curves, to describe difference in parameters A and B of the varieties in different crop seasons and to correlate the derived parameters with mean yield of varieties and their mean sucrose content in juice. Besides, (c) correlations between the efficiency indices of growth and the mean daily growth rates of varieties in different trials have been worked out to show the relationship between these two parameters. In prospecting yields, the importance of the study of formative growth values and millable cane characters is quite obvious. These characters were studied in the year 1942-1943 in both the medium-early and mid-season series. Collectively all these investigations throw some light on cane growth and functions associated with it.

Growth relative to environment. It is a patent fact that environment as well as inherited differences affect the behaviour of the same variety in different years. Besides the inherent differences in the nature of the protoplasm, other internal factors such as osmotic concentration of cell sap, number and size of growing points and the relative availability of manufactured food are some of the factors which determine growth. These factors may be markedly altered by the external conditions and according to Briggs [1928] and Gregory [1928] the external conditions merely accelerate or retard the way in which the internal factors such as temperature light, moisture, electricity and the amount and composition of the materials in the soil influence growth. Of these temperature is by far of greater importance than other environmental factors. Miller [1938] states, " In general, the growth curve in relation to temperature shows three cardinal points, the minium, the lowest temperature at which growth is exhibited ; the optimum, the temperature at which growth is the greatest ; and the maximum, the highest temperature at which growth will occur. "Optimum temperature means favourable conditions for assimilation and growth during the day time. Das [1933] has taken 70°F. as the threshold value for the optimum temperatures. The temperature values above this limit have been termed as day degrees. Comparable results for two years of the varietal trials are available for comparison and for a study of the influence of day degrees on growth of the crop. These results are presented in Table XV.

TABLE XV

Initial growth in relation to day degrees (A—growth in cm. ; B—day degrees.)

Year	Particulars of experiment	Growth in different months						Mean parameter A values
		April		May		June		
		A	B	A	B	A	B	
1941—1942	Medium-early	9·42	+21·2	9·43	+29·3	28·32	+37·6	9·243
1942—1943	Medium-early	7·00	+19·3	7·21	+27·7	14·16	+32·5	2·725
1941—1942	Mid-season	8·09	+21·2	10·75	+29·3	24·75	+37·6	7·21
1942—1943	Mid-season	6·95	+19·3	7·55	+27·7	17·64	+32·5	5·80

Approximately in 1941-1942 the day degrees were higher by two units per day (+60°F. per month) for the months of April and May and about five units higher for the month of June (+150°F.) compared to 1942-1943 and the influence of these differences is marked on the development of varieties both in the medium-early and mid-season series. This effect is particularly in evidence in the growth accumulated in the months of June when the cumulative effect of temperature was manifested more pronouncedly than that in the preceding months. The medium-early varieties comparatively suffered less than mid-season canes. The comparable elongation in April and May was also less. The parameter A of the exponential height growth curves in the two varietal trials in the two years indicated differences of the similar type as in the monthly growth accumulations noted above. These comparable data do bring out somewhat in relief the influence of day degrees on early growth of the crop and confirm the conclusions of Das [1933] and Shaw and Sweezy [1937] that day degrees bear a relationship to the growth of the crop. Agee [1930] and Summerville [1944]

have suggested that the growth made is actually represented about a month after it had set in. Assuming that to be the position the difference in mean growth represented in June should be attributable to April and to May temperatures. It is thus probable that low day degrees in April and May more affected the accumulation of growth in June, when the elongation process could also show marked differences, than in the values for May or April themselves. Apparently maximum temperatures above 70°F. very vitally influence the elongation process in the plants.

Cumulative growth in length. Differences in the cumulative growth amongst the varieties in every trial and in each one of the years are more clearly apparent in sigmois curves draw and represented in Fig. 1. The general analysis of the data is given in Table XVII.

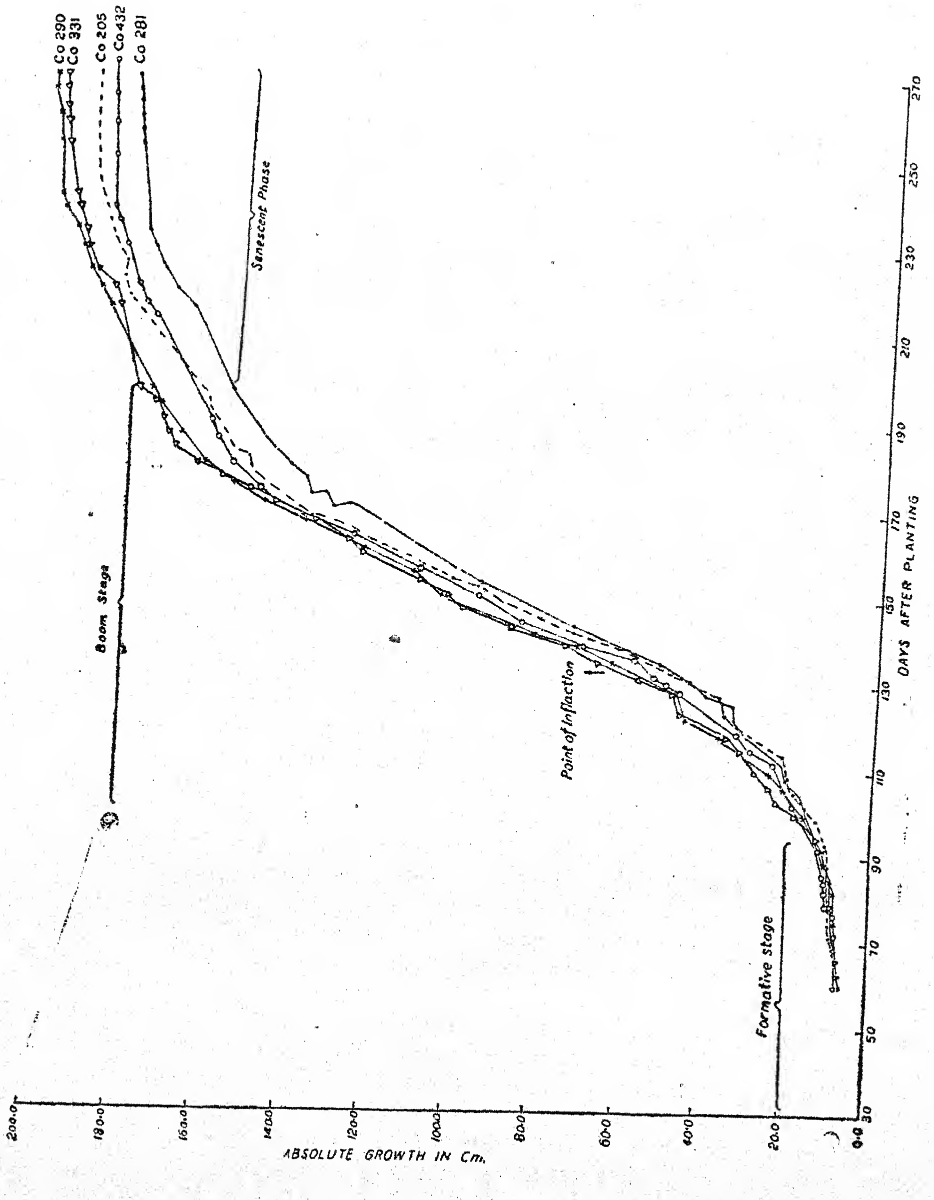

Fig. 1. Cumulative growth curves.

TABLE XVI

Differences in cumulative growth : A—Days in formative, boom and senescent phases ; B—Approximate mean growth in cm.

Year	Name of trial	Nature of crop	Period of growth						Total	
			Formative		Boom		Senescent			
			A	B	A	B	A	B	A	B
1940—1941	Physiological	Plant	95	13	100	152	50	21	245	186
1941—1942	Medium-early	Plant	70	19	130	216	45	50	245	275
1941—1942	Mid-season	Plant	45	13	150	217	50	22	245	242
1942—1943	Medium-early	Plant	130	18	90	139	25	12	245	169
1942—1943	Mid-season	Plant	80	18	100	146	65	13	245	177
1942—1943	Mid-season	Ratoon	120	18	140	221	50	13	310	252
1943—1944	Medium-early	Ratoon	110	21	100	125	70	13	280	159
1943—1944	Mid-season	Plant	85	13	110	148	50	70	245	268

In the preceding section it has been pointed out that season in 1941-1942 was more favourable than in 1942-1943 for the early development of the crop in the medium-early and mid-season series. The data presented in Table XVI indicates that while in 1941-1942 the formative period for the medium-early and the mid-season series comprised of 70 and 45 days respectively, it took 130 and 80 days to complete the process in 1942-43. Therefore, the 'grand period of growth' extended over a longer period in the former season than in the latter year. Shortness of the elongation period in the boom stage considerably reflected in the growth accumulated. While in 1941-1942 the growth put on was 216 and 207 cm. by the medium-early and the mid-season series, in 1942-1943 it was 139 and 146 cm. respectively. The growth in height of the plants was reduced not only in the boom stage but also in the senescent stage of the crop. The growth made respectively was 50 and 22 cm. in the former and 12 and 13 cm. in the latter year.

In the same year, i.e. 1942-1943, the crop growth during the formative period was similar, but the boom stage being longer in the ratoon than in the plant crop, the former crop in the grand growth stage accumulated more growth than the ratoon crop. The results of the medium-early ratoon crop give added support to the above results in this respect. Here the period of elongation was limited to 100 days only and therefore, the actual growth put on was 125 cm. only.

Thus in the process of growth a time factor may operate to limit the elongation of cells during the grand period stage of the crop. 'This ability to grow rapidly is a distinct advantage to an organism where there is a time limit to its period of growth' [Miller, 1938].

Exponential height growth curves and performance of varieties. Priestley [1929] distinguishes three stages in the growth of cells, namely, (a) embryonic or formative stage, (b) the stage of elongation, and (c) the stage of differentiation. Differentiation according to Loomis [1932] is the sum of the morphological changes that start during cell enlargement and end with the death of the cell. A cell after differentiation solely functions for helping other cells to grow and develop. After the maximal enlargement of the cell has taken place, it tends to become a specialized cell, e.g. a sieve tube, a trachied, etc. A specialized cell invariably continues to be what shape it attains after maximal enlargement.

Analogous three stages of development are observed in each plant part or organ. Thus each organ has its formative stage, grand growth (elongation) stage and its stage of differentiation or maturition. The elongation of any part begins at a slow rate that gradually increases to a maximum after which the rate progressively falls off until enlargement ceases. The embryonic stage commingles with the rate of development in the initial stages of plant life and the stage of maturition or differentiation with the progressively decreasing rate of elongation of plant organs. These three stages have been distinctly indicated by the cumulative growth in length curves of the varieties in the experiments described above (Fig. 1).

MacDougal [1916, 1921] from his extensive studies concluded that in the formative period before cells divide they increase in volume by the protoplasmic hydration. This stage he called acceration stage of the cells. During this stage, proteins and carbohyderates are formed by synthesis, dehydration and condensation [MacDougal, 1925]. When the mass of a cell reaches a certain point, cell division begins.

In these cells protein synthesis is dominant, while carbohydrate metabolism and storage is at its minimum. After the cell has been formed it needs to strengthen its cell wall which may stand the stress of increasing turgor. Therefore the protoplasm after the formation of new cells tends towards carbohydrate synthesis rather than protein synthesis [Priestley, 1928, 1929]. MacDougal [1919], in the leaves of *Crassulaceae*, in the joints of cacti and in fruits, observed little increase of dry matter, although growth as measured by the change in form was recorded. The proportion of water and solid matter thus underwent but little change. Freeland [1933] observed in *Bryophyllum* that osmotic pressure of the margins of the proliferating leaves was in general higher than that of the paired, inactive leaves. By this osmotic action the volume of the plant cell increases several hundred times and yet contains very little extra protoplasm than before expansion began. This occurs without the expenditure of energy necessary to manufacture relatively large quantities of protoplasm.

In the preceding section comparative exponential height growth curve values of varieties in the eight trials have been given in Tables I, II and VI. The exploratory correlations worked out have shown that although the value of initial rapidity of growth (A value) are correlated positively with the cane yield in all the eight trials, the extent of correlations is low and non-significant in all except two cases in which the significance of the coefficients between the two was high (Table XVII). This indicates that the initial rapidity of growth possessed by the varieties is not the chief factor on which the yield depends, other factors also modify the yield of the crop.

Also from the above quoted evidence it may be observed that as cell division and protein synthesis chiefly take place during the embryonic or early growth of the crop and in the rapid elongation process the protein synthesis takes place at a low rate, early growth or initial potential of growth must influence a good deal the total likely growth to be made by the plant, for, however favourable the environment in the rapid elongation period may be, the growth must be limited by the embryonic outlay in the plant in the formative stage.

TABLE XVII

Summarized correlation coefficients

Year	Nature of the trial	Nature of the crop	Correlation coefficient: Between A and mean yields	Correlation coefficient: Between b value and mean sucrose per cent
1940—1941	Physiological	Plant	+0·28	+0·98***
1941—1942	Medium-early	,,	+0·326	+0·926***
1941—1942	Mid-season	,,	+0·41	+0·593
1942—1943	Medium-early	,,	+0·818**	+0·915***
1942—1943	Mid-season	,,	+0·382	+0·713*
1942—1943	Mid-season	Ratoon	+0·536	+0·933***
1943—1944	Medium-early	,,	+0·556	+0·711*
1943—1944	Mid-season	Plant	+0·817**	+0·785*

***Indicates significance at $P=0{\cdot}01$ **Indicate significance at $P=0{\cdot}05$ *Indicates significance at $P=0{\cdot}10$

In other words with limited number of cells formed in the initial stage of plant life, however rapid and large the distension of cells may be, the total mass of tissues would remain small. Varieties possessing high initial rapidity of growth or A value generally have been observed to yield more than with low A value.

The correlation coefficient values between parameter b and mean sucrose percentage in the juice over the crushing season were significant in seven out of eight trials. This indicates that the study of b values have shown more intrinsic value than that postulated by Blackman [1919]. He simply referred to the rate of production of dry matter, while our studies show that a variety may, by virtue of its initial rapidity of growth, gain advantage and produce a larger amount of dry matter, but it may not have a large b value or relative growth rate of the crop, which in sugar cane indicates better sugar accumulating power in the plant.

The values of the relative growth rate of varieties in the two trials over the entire period of study extending over three years are shown in Table XVIII. The differences in each of the trials in respect of the b values of the varieties have already been explained. We discuss them from another aspect here. Briefly, it will be noted that in both the years in the medium-early trial variety Co281 had the highest value of b and Co312 the lowest; other varieties occupied, with slight variations, a mid-position between the two. Similarly in the mid-season trial Co534 had the highest position in respect of b values in all the years, other varieties indicated small differences amongst themselves. Broadly speaking, then, the varieties maintained a similar level of efficiency of growth in the different years. Summerville [1944] considers this to be conferred by the genetical constitution of the varieties.

TABLE XVIII

Value of b *in different years in plant crop*

Nature of experiment	Variety	1941-1942	1942-1943	1943-1944
Medium-early series	Co312	0·01433	0·01284	
	Co281	0·01785	0·01848	
	Co299	0·01595	0·01842	
	Co313	0·01643	0·01786	
	Co427	0·01556	0·01653	
	Co549	0·01544	0·01829	
Mid-season series	Co290	0·01687	0·01686	0·01499
	Co312	0·01598	0·01677	0·01323
	Co331	0·01472	0·01744	0·01343
	Co419	0·01809	0·01885	0·01399
	Co438	0·01739	0·01742	0·01454
	Co451	0·01759	0·01537	0·01455
	Co534	0·01824	0·01948	0·02181

In Table XIX are given the comparative data for the plant and ratoon crops of the mid-season series to show that by ratooning both b and A parameters are modified for instance.

TABLE XIX

Mid-season series—plant versus ratoon crop 1942-1943

Comparison of parameters A *and* b *with acre yields and mean sucrose percentage in juice*

Variety	Plant		Ratoon		Plant		Ratoon	
	Parameter A value	Mean yield in md.	Parameter A value	Mean yield in md.	Parameter b value	Mean percentage of sucrose	Parameter b value	Mean percentage of sucrose
Co290	6·91	375	5·96	669	0·01686	12·12	0·01396	11·50
Co312	5·83	457	4·19	744	0·01677	11·47	0·01474	12·37
Co331	7·56	339	5·00	1012	0·01744	12·58	0·01532	12·18
Co419	4·53	182	3·18	709	0·01885	12·62	0·01639	12·12
Co438	5·46	429	3·04	529	0·01742	11·73	0·01639	11·91
Co451	6·55	272	0·68	644	0·01537	12·04	0·02393	13·55
Co534	3·76	272	1·25	537	0·01948	13·11	0·02181	13·18
Value of r=	+0·382		+0·536		+0·713*		+0·933***	

Co451 behaved rather in an interesting manner. In spite of its maintaining a high yield level, almost equal to Co290 in the ratoon crop, it developed more sugar in juice than the latter. The accumulation of high sugar was a consequence of the high efficiency of growth of the crop under consideration. On the contrary, Co331 developed more in yield in ratooning and its efficiency index was lowered and a corresponding fall in sugar content of the juice was noticed. Evidently when the plant has a tendency to develop mass, it diverts its sugar for synthesis into cellulose and in effect the sugar accumulation suffers, which is indicated by a low growth efficiency of the crop. On the contrary, when there is a tendency to accumulate sugar, the crop tends to depress its yield, for its sugar does not transform into larger amount of cellulose which may allow greater distension in the cells. The ratoon crop obtains advantage of the time factor. Therefore, given the initial requirements of mineral matter, under favourable environment, not only the ratoon crop of the variety is able to accumulate greater growth in stalk length but develop a greater relative growth rate generally, unless there is something genetically inhibiting in the variety, and thus accumulate more sugar in the plant.

Interrelationship between A *and* b *values and its interpretation.* In general the data given in Tables I, III and VI revealed that when a variety indicated high initial rapidity of growth, it very often possessed low efficiency index value and vice versa. This fact was found to hold good in all the four years in which eight trials had been conducted. The probable explanation for it appears to be that when protein synthesis is active, meristem forms quickly and its outlay is greater and, in consequence, when the elongation process starts, meristem elongates in proportion, unless the plant suffers from water shortage to the total outlay of the meristem. The sugars in that period instead of accumulating are utilized for greater cellulose formation, to strengthen the distending cell walls and not stored as saccharose in the cane stem. On the other hand, when the meristem developed in the embryonic stage is small, the total elongation that can take place is small and a small amount of hexoses is comparatively required for the formation of cellulose. When the maximum requirement of cellulose for the fewer number of cells is satisfied the remaining sugars are accumulated in the form of cane sugar in the cane stem. As such, it is observed, that when A value, or the initial rapidity of growth, is high in a variety, its corresponding b value is low and vice versa.

Underground branching differences in varieties. In both the varietal trials, namely, medium-early and the mid-season series, very wide differences in tillering were observed amongst the varieties. Varieties with larger number of tillers matured earlier than others only in the former trial. This partially, confirms the findings of Barber [1919]. Again, in both the trials varieties generally developed, in the absence of any epidemic, more healthy shoots than those showing mortality. Thus the proportion of the matured stalks was larger than immature stalks. It was also noticed that the major portion of the millable canes was formed of the mother shoots together with b type of shoots or shoots of the second order and it is these shoots which should be encouraged in the season to contribute towards greater yield of the crop. Besides the mother shoots, second order shoots are the first to appear and since it is these which need encouragement it will not be too much to presume that the crop manuring is indicated early in the season in this tract and should be applied in time to induce their rapid growth. Late manuring is likely to encourage greater production of c type of shoots which as we have noticed, remain immature or die prematurely. This happens, as Barber [1919] has pointed out, because of the lack of light space by which late developed shoots get at a disadvantage as they are overshadowed by their neighbours. He goes on to state, 'It is fairly certain that this death of shoots is not due to lack of food supply in the soil, for this can and habitually is supposed to meet all possible needs..
Light is perhaps the most important limiting factor as regards tillering'. Besides the light factor, he has discussed the influence of soil moisture, manuring and spacing on tillering. He considers that these factors may limit tillering, they seldom cause high mortality under normal conditions.

Millable cane values of varieties and crop estimation. Varieties exhibited as large variations in millable cane characters as in their underground branching. These cane values point to the fact that where varieties have low germination or low tillering and the crop does not have a rapid initial start, the weight per unit length, height of the millable stalks, thickness of joints, etc., make up for the increase in the yield of the variety. The instance of variety Co419 may be cited in this

connection. This variety on the whole possesses a low tillering and a low A value, but this loss is made good by the larger girth of the cane and greater millable length of the stalks. Contrary to this, the yield in Co312 is made up by greater tillering of the crop and a high A value of growth than by the girth or length of the stalks. Thus it will be observed that though for a single variety crop estimation may be done by a simple formula as given by Shaw and Sweezy [1937], it is not possible to have a common formula when varieties differ in so many respects. It is, however, possible to find out partial regression equations between yield as the dependent variable and other contributing factors as the independent ones. Such derived equations for the varieties would illustrate the contribution of each growth factor to the yield of the varieties. The possibilities of this procedure are now being investigated.

Summary

The paper deals with four years' investigations on growth in length in the various trials. In the year 1941-1942 the underground branching and millable cane characters of varieties in two of the trials were also studied.

Varieties exhibited wide differences in all the eight trials in their cumulative growth data year after year amongst the various varieties. In years with short formative periods the grand growth period correspondingly increased, which helped the elongation process in cane stalks. The ratoon crop gained advantage over the plant crop in this manne r end accumulated larger growth by harvest. Thus it is shown that where there is a time limit to the p riod of growth the ability to grow rapidly is a distinct advantage for the variety.

Varieties possessing high A values usually had low b values in the exponential height growth curves. The correlation coefficient values between the parameter b and mean sucrose percentage in juice over the entire ripening period, were significant in seven out of eight trials. The correlation values between A and the mean yield values of the varieties were low and significant in two out of eight trials only. Subject to environmental influences the varieties generally maintained a similar level of efficiency indices in the various years. This is presumed to be conferred by the genetical constitution of the varieties. Ratooning modified the efficiency indices and initial rapidity of growth values of the varieties. The significance of these results has been discussed in the paper.

Studies on underground branching of varieties indicated that most of the crop of millable stalks is formed of mother shoots together with shoots of the second order. Late formed shoots, principally composed of third order shoots, mostly remained immature or died prematurely. It is deduced from the results that early manuring will be helpful for inducing vigour in early formed tillers which mature into millable canes.

Millable cane characters such as weight per unit length of the stalk, girth of joint, etc., may be contributing factors towards yield of the varieties which possess low initial potential of growth and low tillering per clump. The estimation of crop yield, therefore, cannot be based on a simple formula as suggested by some of the Hawaiian workers. All these factors must be taken into account in working out partial regression equations of yield for the different varieties.

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STUDIES IN TILLERING AND ARROWING IN CO421 AT ANAKAPALLE*

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(With three text-figures)

Tillering and arrowing are two of the most important factors that influence yield in sugarcane. A variety which does not tiller well yields usually fewer canes per unit area and hence may record lower yields. Arrowing limits vegetative development and therefore the yield. Normally canes put forth arrows in October-November in these parts. Although the grand period of growth extends only from June to October, non-flowering canes put on growth to a smaller or greater extent even later on. This amount of cane growth will be lost to the cultivator if varieties arrow in October or November.

Several inherent and environmental factors affect tillering and arrowing. An experiment designed to study the influence of the age of shoots on their arrowing and juice quality was laid out at Anakapalle and was conducted for three consecutive years from 1940-1941 onwards. Information regarding tillering and incidence of shoot borers could also be gathered incidentally from this experiment and is presented below.

Material and methods

Sugarcane is generally planted in this station in the month of March. One budded sets of Co421 were planted ten inches apart in the row and 2 ft. 8 in. apart between rows in about 20 cents of land.

*This formed part of the work which is being carried out at the Agricultural Research Station, Anakapalle, in the scheme partly financed by the Imperial Council of Agricultural Research. Salient features of this paper were published in the Annual Reports of this station.

Over a basal dressing of five tons of farm yard manure one hundred pounds of nitrogen was applied to this crop as a top-dressing in two equal doses at planting and trenching times respectively. In the matter of irrigation and other treatments the crop was treated just as any other normal crop on the station.

Plantings were done on the 5, 10 and 8 March during 1940-1941, 1941-1942 and 1942-1943 respectively. Starting from the 15 day after planting, about 1,000 plants were marked at random each year, by labelling them as shown in Fig. 1. After thus selecting 1,000 plants, tillers which arose from them were marked till the end of August at four day intervals in the same manner as the parent shoots. On each day of marking the youngest shoots which just appeared above ground were put down as having arisen on that date. From the beginning of September fresh tillers which came up from these thousand plants were removed as they were not likely to grow up into mature canes by the usual harvest time (February-March) of this variety.

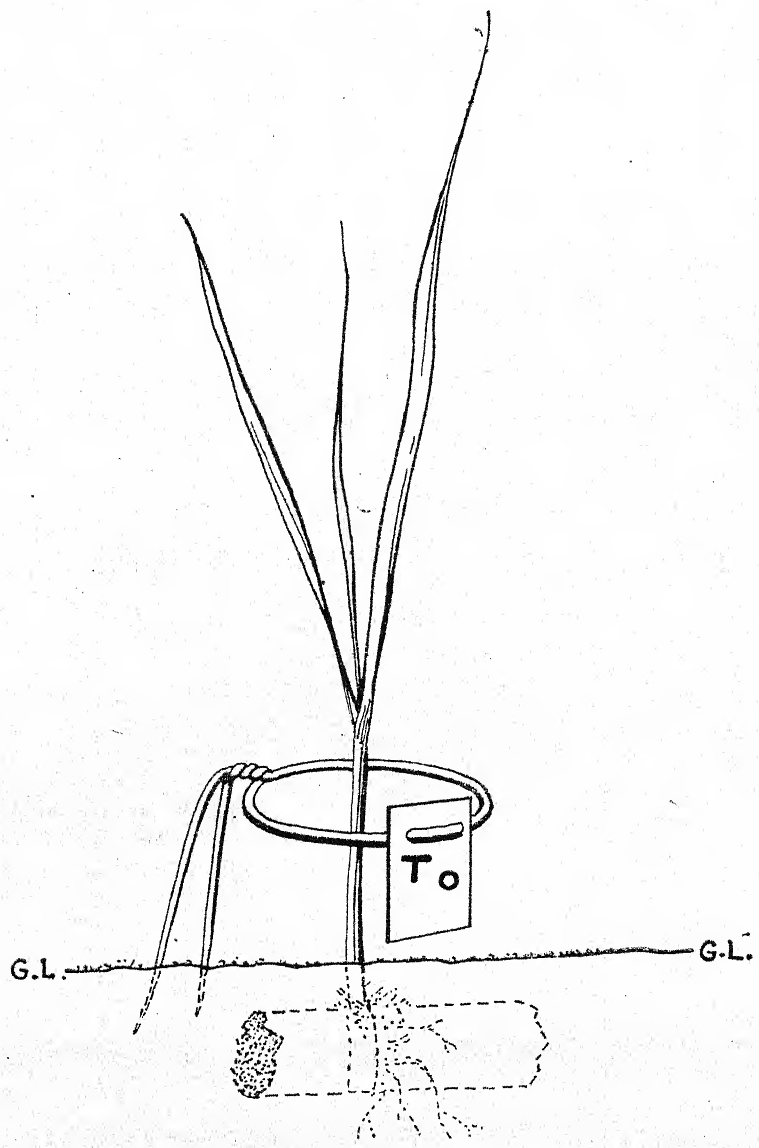

Fig. 1. Labelling of plants

Mortality of shoots due to the incidence of shoot borers was noted in this experiment. Chemical analysis of juices of shoots which arose till about the end of May was also done during the three years this experiment was conducted.

Results and discussion

Tillering and its periodicity. Marking of the 'mother shoots' was completed by 31 March in the first year, 28 March in the second year and 26 March in the third year of this experiment. From certain pot culture experiments Ramiah and Varahalu [1938] deduced that 'there exists a minimum limit for the vegetative growth of any cane variety before the attainment of which no tillers would begin to form'. From this experiment it was found that a minimum growth period of four days was required for a mother shoot to put forth a tiller in 1940-1941, five days in 1941-1942 and twelve days in 1942-1943. The following are the details :—

Table I

Details of tillering

1940-1941		1941-1942		1942-1943	
Date of marking of mother shoot	Earliest date of origin of a tiller	Date of marking of mother shoot	Earliest date of origin of a tiller	Date of marking of mother shoot	Earliest date of origin of a tiller
19th March	31st March	24th March	1st April	24th March	3rd April
23rd March	31st March	26th March	1st April	26th March	1st April
27th March	31st March	28th March	9th April	22nd March	3rd April
31st March	8th April				

'Tillering is the multiplication of shoots in the young plants from the lower short jointed portion of the stem immdediately below the ground' [Barber, 1919]. According to Stubbs [1900] suckering depends largely upon room and there is no practical end to the process of suckering provided ample room is given. Light is perhaps, as Barber says, the most important factor affecting tillering. According to Locsin [1936] also sun exposure is a limiting factor for cane growth. It determines the maximum density of population in a field of cane. Hence before there is overcrowding of tillers and lack of room for further development, i.e., in the initial stages of the crop itself, it is reasonable to expect maximum tillering activity. The results of this experiment bear this out.

During all the three years, active tillering phase commenced during the third week of April and extended till the end of May (Fig. 2), except during 1941-1942, when there was a slight revival of the tillering activity towards the end of July. Less than one per cent of the total number of shoots arose on each day of marking earlier or later than this period. Hence maximum number of tillers in Co421 will be formed from the third week of April till the end of May in this locality. In a manurial experiment at Padegaon [1935-1936] in which single budded sets were planted by about the middle of January, maximum number of tillers were formed in April and May alone as at Anakapalle.

Factors that influence the survival and mortality of shoots. Stubbs [1900] at Louisiana observed that over one half of suckers formed died. According to Arceneau [1935] 'Invariably, however, more tillers are produced than can be successfully brought to maturity'. Locsin reports from Philippines that the suckers reach a maximum number, 4 shoots per foot of row, when the cane is 4 to 5 months old, declining afterwards to about 2·4 stalks per foot row.

On an examination of the data in this experiment (Table II) it will be seen that the average number of shoots produced for every plant studied was 6·742 in the first year, 8·491 in the second and 6·133 during the third year. Out of these only 3·441, 2·065 and 1·937 shoots per plant survived during the three years respectively.

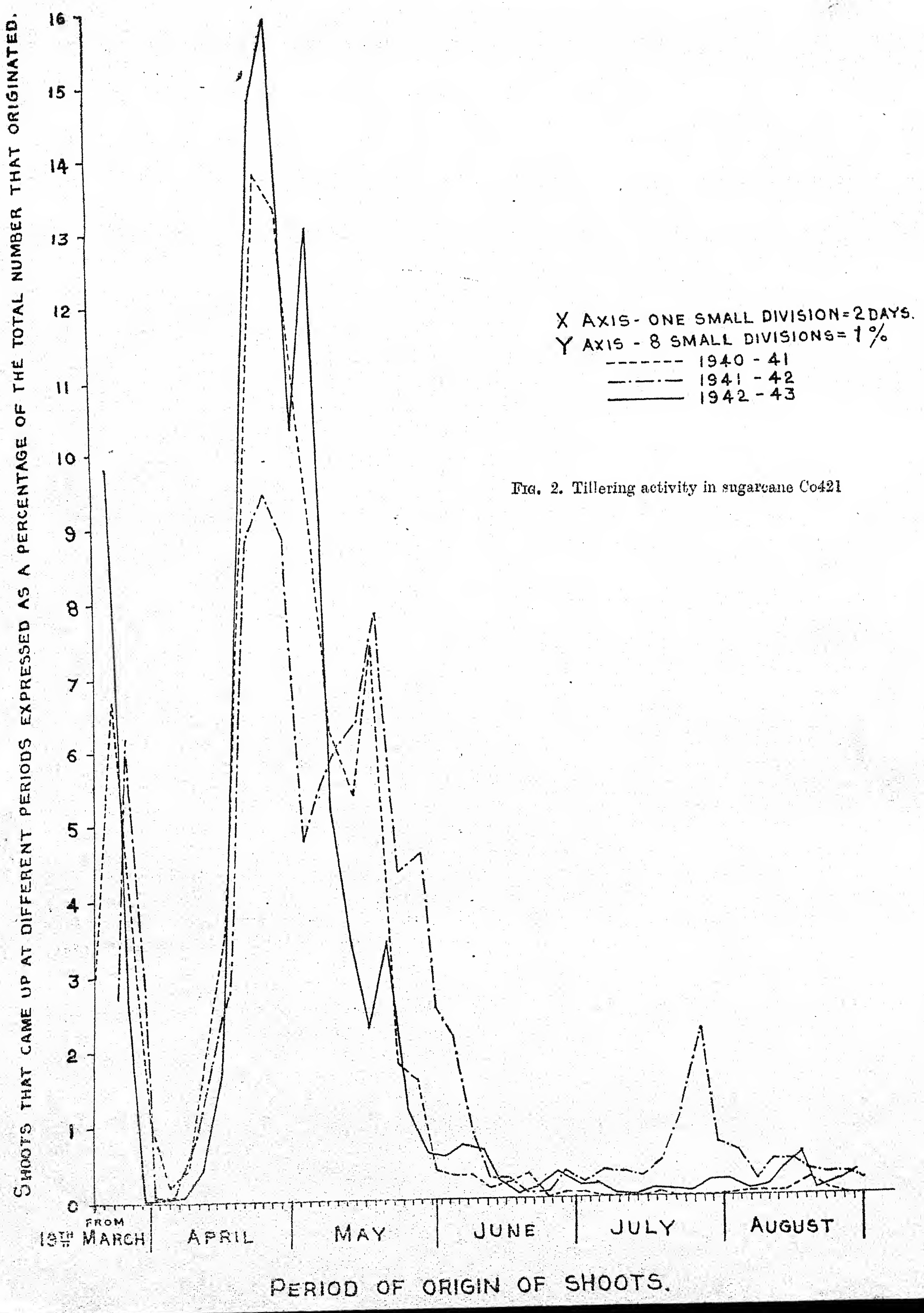

FIG. 2. Tillering activity in sugarcane Co421

TABLE II

Details Regarding the Origin and Survival of Shoots Arising on Different dates of Marking

1940-1941 (Planted 5 March 1940)

Date of marking or origin of shoots	Number of shoots originated	Shoots arising on dif. dates as percentage of total No. originated	Number of shoots that survived	Surviving shoots as percentage of total living population
19th March	204	3·026	148	4·301
23rd ,,	451	6·689	330	9·590
27th ,,	280	4·153	209	6·074
31st ,,	72	1·068	40	1·162
4th April	15	0·222	8	0·232
8th ,,	30	0·445	23	0·668
12th ,,	142	2·106	108	3·139
16th ,,	241	3·575	191	5·510
20th ,,	540	8·009	386	11·218
24th ,,	927	13·745	657	19·093
28th ,,	900	13·349	521	15·141
2nd May	731	10·842	337	9·794
6th ,,	546	8·098	183	5·318
10th ,,	425	6·304	126	3·662
14th ,,	363	5·384	69	2·005
18th ,,	501	7·431	60	1·744
23rd ,,	120	1·780	13	0·378
27th ,,	106	1·572	18	0·523
31st ,,	27	0·400	2	0·058
4th June	23	0·341	3	0·087
8th ,,	21	0·311	..	..
12th ,,	10	0·148	1	0·029
16th ,,	13	0·193	..	..
20th ,,	19	0·282	2	0·058
24th ,,	..	..	..	..
28th ,,	5	0·074	..	..
2nd July	4	0·059	..	..
6th ,,	..	..	..	..
10th ,,	..	..	..	..
14th ,,	..	..	..	..
18th ,,	2	0·030	..	..
22nd ,,	..	..	..	..
26th ,,	..	..	..	..
30th ,,	..	..	..	..
3rd August	1	0·015	1	0·029
7th ,,	1	0·015	..	..
11th ,,	3	0·044	1	0·029
15th ,,	..	..	..	..
20th ,,	15	0·222	3	0·087
24th ,,	4	0·059	1	0·029
28th ,,	..	..	..	..
Total	6742		3441	

1941-1942 (Planted 10 March 1941)

Date of marking or origin of shoots	Number of shoots originated	Shoots arising on dif. dates as percentage of total No. originated	Number of shoots that survived	Surviving shoots as percentage of total living population
24th March	230	2·716	127	4·945
26th ,,	524	6·187	288	11·215
28th ,,	242	2·857	126	4·901
1st April	6	0·071	..	..
5th ,,	7	0·083	1	0·039
9th ,,	70	0·827	30	1·168
13th ,,	149	1·759	65	2·531
17th ,,	227	2·680	116	4·517
21st ,,	750	8·844	356	13·863
25th ,,	799	9·434	351	13·668
29th ,,	744	8·785	276	10·748
3rd May	404	4·770	119	4·634
7th ,,	469	5·538	126	4·901
11th ,,	616	7·274	124	4·829
15th ,,	547	6·459	126	4·901
19th ,,	664	7·840	114	4·439
23rd ,,	370	4·369	42	1·636
28th ,,	388	4·581	45	1·752
31st ,,	214	2·527	27	1·051
4th June	176	2·078	17	0·662
8th ,,	65	0·768	6	0·234
12th ,,	22	0·260	4	0·156
16th ,,	20	0·236	3	0·117
20th ,,	7	0·083	..	..
24th ,,	6	0·071	2	0·078
28th ,,	28	0·331	4	0·156
2nd July	18	0·213	1	0·039
6th ,,	31	0·366	1	0·039
10th ,,	30	0·354	3	0·117
14th ,,	26	0·307	6	0·234
18th ,,	39	0·461	5	0·195
22nd ,,	88	1·039	6	0·234
26th ,,	189	2·232	10	0·389
30th ,,	61	0·720	8	0·312
3rd August	52	0·614	7	0·273
8th ,,	17	0·201	4	0·156
11th ,,	40	0·472	4	0·156
15th ,,	40	0·472	1	0·039
19th ,,	30	0·354	6	0·234
23rd ,,	23	0·272	4	0·156
27th ,,	23	0·272	1	0·039
31st ,,	19	0·224	4	0·156
	8469		2566	

1942-1943 (Planted 8 March 1942)

Date of marking or origin of shoots	Number of shoots originated	Shoots arising on dif. dates as percentage of total No. originated	Number of shoots that survived	Surviving shoots as percentage of total living population
22nd March	573	9·783	276	14·919
24th ,,	224	3·824	105	5·676
26th ,,	158	2·698	70	3·784
30th ,,	..	..	..	..
3rd April	2	0·034	1	0·054
7th ,,	5	0·085	3	0·162
11th ,,	24	0·410	13	0·703
15th ,,	100	1·707	50	2·703
19th ,,	352	6·010	177	9·568
23rd ,,	868	14·820	399	21·568
27th ,,	931	15·895	369	19·946
1st May	602	10·278	158	8·541
5th ,,	765	13·061	130	7·027
9th ,,	301	5·139	28	1·514
13th ,,	202	3·449	24	1·297
17th ,,	132	2·254	9	0·486
21st ,,	204	3·483	9	0·486
25th ,,	71	1·212	3	0·162
29th ,,	37	0·632	2	0·108
2nd June	34	0·581	2	0·108
6th ,,	43	0·734	..	..
10th ,,	37	0·632	..	..
15th ,,	12	0·205	1	0·054
18th ,,	2	0·034	1	0·054
22nd ,,	8	0·137	..	..
26th ,,	21	0·359	1	0·054
1st July	9	0·154	1	0·054
4th ,,	11	0·188	..	..
8th ,,	5	0·085	..	..
12th ,,	1	0·017	..	..
16th ,,	4	0·068	..	..
20th ,,	5	0·085	2	0·108
24th ,,	2	0·034	..	..
28th ,,	9	0·154	1	0·054
1st August	9	0·154	2	0·108
5th ,,	1	0·017	1	0·054
9th ,,	4	0·068	1	0·054
13th ,,	21	0·359	2	0·108
17th ,,	35	0·598	6	0·324
21st ,,	5	0·085	..	..
25th ,,	11	0·188	2	0·108
29th ,,	17	0·290	1	0·054
	5857		1850	

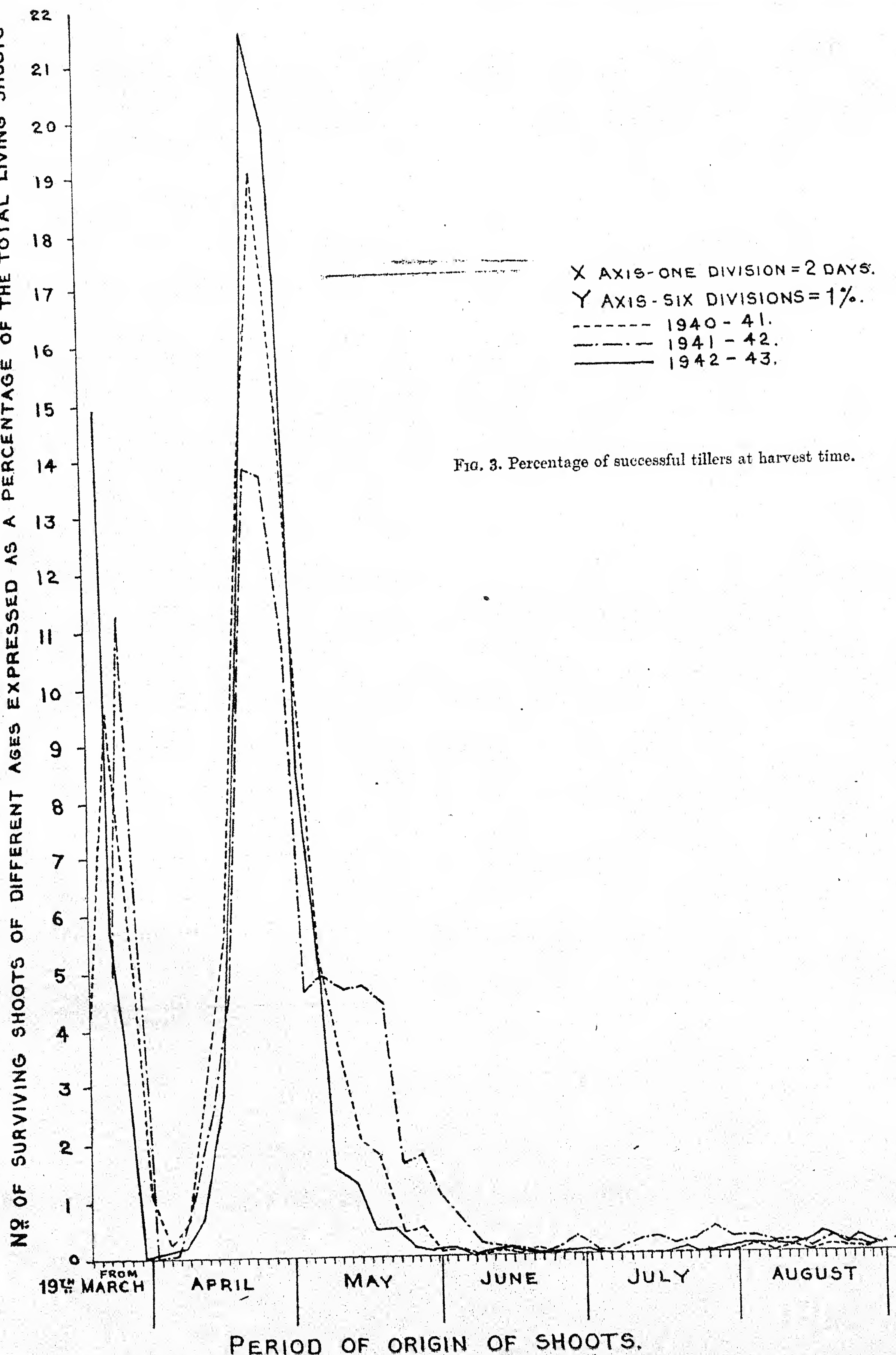

Fig. 3. Percentage of successful tillers at harvest time.

This progressive decline in the number of surviving shoots was due to the unfavourable climatic conditions during the second and third years (vide Appendix—meteorological data, Anakapalle). Distribution of rainfall was even only in the first year. Relative humidity decreased, in general, progressively from year to year and mean maximum temperatures in the early stages of crop growth increased gradually year after year. Among the surviving shoots at harvest time those that originated in April and May formed 78·52 per cent, 74·75 per cent and 74·32 per cent during the three years respectively. Thus the greatest number of successful tillers in the crop originated in the months of April and May alone (Fig. 3). In the experiment at Padegaon [1935-1936] cited before similar results were obtained.

As regards the relationship between age of shoots and their survival, it is seen from Table III that from March to June there was a progressive decrease and then a tendency towards increase in the percentage of surviving shoots to those originated in the same month.

TABLE III

Number of shoots originated and the percentage of surviving shoots to those which arose in the same month

Month	1940-1941			1941-1942			1942-1943		
	Total shoots originated	Surviving shoots	Percentage	Total shoots originated	Surviving shoots	Percentage	Total shoots originated	Surviving shoots	Percentage
March	1007	727	72·19	995	541	54·32	955	451	47·23
April	2795	1894	67·76	2752	1195	43·44	2282	1012	44·34
May	2819	808	28·66	3572	723	20·24	2314	363	15·69
June	91	6	6·59	324	36	11·11	157	5	3·18
July	6	..	..	482	40	8·29	46	4	8·70
August	24	6	25·00	244	31	12·70	103	15	14·56

Total for the three years

Month	Total shoots originated	Surviving shoots	Average percentage
March	2957	1719	58·11
April	7829	4091	52·26
May	8705	1894	21·76
June	572	47	8·22
July	534	44	8·24
August	371	52	14·02

Hence it is not so much the age but other factors, presumably space available, that determine the survival percentage of shoots. Another important point is that successful tillers that arose from June to August constituted a negligible percentage of the surviving population. They formed 0·35 per cent, 4·17 per cent and 1·30 per cent respectively in the three years.

As mentioned already, mortality of shoots due to attack of shoot borers as opposed to other causes was noted in this experiment. Borer damage of stalks which survived even though a number of joints were attacked was not taken into account. The results are presented below (Table IV).

TABLE IV

Borer damage of shoots

		1940-1941			1941-1942			1942-1943		
		Number of shoots	Mortality in shoots due to borer	Percentage	No. of shoots	Mortality in shoots due to borer	Percentage	No. of shoots	Mortality in shoots due to borer	Percentage
Mother shoots		1000	235	23·5	995	415	41·71	955	488	51·10
Tillers which originated	March	7	..	..	..	..	..	..	..	..
	April	2795	749	26·80	2752	1270	46·15	2282	1203	52·72
	May	2819	1444	51·22	3572	1782	49·89	2314	1727	74·63
	June	91	52	57·14	324	124	38·27	157	99	63·06
	July	6	4	66·67	482	192	39·83	46	20	43·48
	August	24	12	50·00	244	51	20·90	103	25	24·27

If we omit out of consideration the insignificant number of shoots that came up from June to August, mortality of 'mother' shoots due to incidence of borers is seen to be less than that in tillers. According to Arceneaux [1935] at Louisiana there was a gradual rise in the percentage of bored joints with a delay in the date of germination within the three sucker groups but the percentage of deaths among mother shoots was much higher than among suckers. This he considers is 'unquestionably due to the fact that borer death counts covered only the early growth period when borer damage was naturally concentrated on mother shoots and older suckers.' The crop which Arceneaux dealt with was planted on 7 October 1933. Mother shoots were marked on 11 April 1934. Group A suckers were marked on 20 April, group B suckers being selected on 29 May. The rest of the suckers were left untagged and constituted group C suckers. And these are the results of only one year's experimentation. Unlike in this case, tillers which arose at particular intervals (4 days) were regularly marked in this experiment (at Anakapalle) for a definite period during all the three years. Mortality of shoots due to borer damage was noted in all the different age groups, but no account was taken of the damage done to individual joints in each stalk. To save space the whole data are not presented here. However, the range of the percentages of deaths due to borer attack in the mother shoots and tillers originating in the different months is furnished below (Table V).

TABLE V

Percentage of deaths due to borer attack

		Range of percentages of deaths due to borer attack		
		1940-1941	1941-1942	1942-1943
Mother shoots		21·07 to 27·78	40·46 to 43·39	50·44 to 53·80
Tillers which arose	April	16·67 to 34·56	38·77 to 83·33	40·00 to 57·68
	May	33·33 to 61·16	38·32 to 56·22	54·05 to 79·07
	June	40·00 to 76·92	33·33 to 60·71	50·00 to 87·50
	July	100 per cent	25·40 to 67·74	22·22 to 100·00
	August	26·67 to 100·00	6·67 to 35·29	14·29 to 75·00

These results are at variance with those obtained by Arceneaux,

Arrowing. Several factors influence arrowing. The inherent tendency of a variety, the seasonal phenomena, effect of environment, and influence of parents are some of the factors. Among the environmental factors which influence the time of arrowing, one of the most important is said to be the photo period or the amount of sunlight received during the different growth periods of sugarcane.*

It is evident from this experiment, that the age of shoot also plays an important part with regard to arrowing. Co421 arrows here usually by about the middle or the third week of November. Among the selected plants, shoots (mother shoots or tillers) that arose up to 18 May in 1940-1941, 3 May in 1941-1942 and 13 May in 1942-1943 only put forth arrows. A minimum growth period of about six months is obviously necessary before a stalk of Co421 can arrow.

TABLE VI

Correlation between time of origin of shoot and arrowing

1940-1941				1941-1942				1942-1943			
Date of marking	Number of living tillers	Number arrowed	Number of canes arrowed as a per centage of living tillers of the same age	Date of marking	Number of living tillers	Number arrowed	Number of canes arrowed as a per-centage of living tillers of the same age	Date of marking	Number of living tillers	Number arrowed	Number of canes arrowed as a per-centage of living tillers of the same age
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
19th March .	148	48	32·43	24th March .	127	1	0·79	22nd March .	276	96	34·06
23rd ,, .	330	93	28·18	26th ,, .	285	2	0·70	24th ,, .	105	23	21·91
27th ,, .	209	39	18·66	28th ,, .	126	2	1·58	26th ,, .	70	22	31·43
31st ,, .	40	4	10·00	1st April .	..	..	..	30th ,, .	..	..	..
4th April .	8	2	25·00	5th ,, .	1	..	..	3rd April .	1	..	..
8th ,, .	23	5	21·74	9th ,, .	30	..	..	7th ,, .	3	1	33·34
12th ,, .	108	24	22·22	13th ,, .	65	..	..	11th ,, .	13	3	23·08
16th ,, .	191	41	21·47	17th ,, .	116	1	0·86	15th ,, .	50	8	16·00
20th ,, .	386	80	20·73	21st ,, .	356	2	0·56	19th ,, .	177	29	16·39
24th ,, .	657	87	13·24	25th ,, .	351	2	0·57	23rd ,, .	399	66	16·54
28th ,, .	521	45	8·64	29th ,, .	276	..	..	27th ,, .	369	36	9·76
2nd May .	337	12	3·56	3rd May .	119	1	0·84	1st May .	158	10	6·33
6th ,, .	183	6	3·28					5th ,, .	130	9	7·14
10th ,, .	126	1	0·79					9th ,, .	28	2	7·14
14th ,, .	69	..	..					13th ,, .	24	1	4·16
18th ,, .	60	1	1·67								

*Annual Report of the Imperial Sugarcane Expert (period ending 30-6-1938).

The percentage of arrowed stalks to total living shoots at harvest time was 14·19 during the first year and 16·55 during the last year. In the second year there was very little arrowing (0·43 per cent). Significant positive correlation, (value of r being $+0{\cdot}8687$ and $+0{\cdot}5482$ at $P=0{\cdot}05$ in the first and third years respectively) was observed between age of shoot and arrowing in the first and third years. [For working out the correlation, the age of shoot is determined as follows: A definite date, end of November, by which time arrowing will be almost complete in this variety, is fixed. The interval (in days) between time of origin 19 March, 23 March etc., and 30 November is taken as the age of the shoots which arose on the different dates. The percentage of arrowing in each age group (Table VI) is known. Correlation coefficient is worked out from this data].

Juice quality. Age is an important factor that influences the sugar content of cane juice. Very young canes will be immature and have poor juice quality. Aged canes will be over ripe and may have poor quality juices. 'In subtropical regions like Louisiana where even the oldest shoots do not as a rule reach physiological maturity, the age differences involved,are generally regarded as major sources of variation in the sugar content of the juice' [Arcencaux 1935].

Juices of the mother shoots and tillers which arose on different dates till 18 May in 1940-1941, 28 May in 1941-1942, and 21 May in 1942-1943 were analysed periodically for sucrose and purity values in this experiment. The number of analyses depended upon material available in the various shoots. Results are furnished below (Table VII).

Table VII

Results of periodical analyses of juices of shoots arising on different dates

Serial No.		Date of origin of shoot	December		January		March		April		May	
			Sucrose per cent	Purity per cent	Sucrose per cent	Purity per cent	Sucrose per cent	Purity per cent	Sucrose per cent	Purity per cent	Sucrose per cent	Purity per cent
							1940-1941					
1	Mother shoots.	19th March 1940	14·87	85·19	16·50	88·76	17·23	88·76	16·07	88·57	16·18	88·69
2		23rd ,, ,,	14·17	82·68	16·96	89·78	17·23	88·76	16·85	88·04	16·95	89·97
3		27th ,, ,,	14·88	85·84	16·51	89·78	18·45	89·95	18·06	89·23	17·37	89·78
4		31st ,, ,,	14·41	84·59	16·77	88·28	18·42	89·37	18·91	90·33	16·98	89·19
5	Tillers.	16th April ,,	14·13	83·95	16·27	87·98	17·88	88·92	18·10	89·43	17·03	89·41
6		20th ,, ,,	14·46	83·08	16·96	89·29	17·89	87·18	17·70	88·46	17·44	91·09
7		24th ,, ,,	14·21	82·94	15·96	86·68	17·11	87·80	18·36	89·51	17·26	89·95
8		28th ,, ,,	14·19	83·40	16·22	88·16	17·86	88·27	17·86	88·88	17·04	89·55
9		2nd May ,,	14·11	83·84	16·30	87·62	17·40	87·72	17·96	88·75	17·67	90·25
10		6th ,, ,,	13·67	81·15	16·25	87·37	18·08	89·02	18·20	89·50	18·15	91·47
11		10th ,, ,,	13·88	82·00	16·12	87·35						
12		14th ,, ,,	13·40	83·02	15·64	85·15						
13		18th ,, ,,	13·33	80·63	14·83	84·96						

TABLE VII—*contd.*

Results of periodical analyses of juices of shoots arising on different dates

Serial No.		Date of origin of shoot	November Sucrose per cent	November Purity per cent	December Sucrose per cent	December Purity per cent	January Sucrose per cent.	January Purity per cent	February Sucrose per cent	February Purity per cent	March Sucrose per cent	March Purity per cent	April Sucrose per cent	April Purity per cent	May Sucrose per cent	May Purity per cent
		1941-1942														
1	Mother shoots.	24th March 1941	12·53	79·80	14·65	85·09	16·93	88·43	16·53	86·34	17·08	89·37	17·76	89·43	17·30	89·82
2		26th „ „	12·53	79·29	14·63	84·48	16·12	87·82	17·40	89·91	18·25	90·76	17·40	87·60	17·99	91·05
3		28th „ „	12·73	78·09	16·08	88·22	17·11	87·96	17·51	89·56	17·63	88·98	17·54	87·44	17·40	87·60
4	Tillers.	17th April „	12·54	78·12	14·81	83·83	17·04	87·83	17·49	89·00	18·58	91·19	17·21	87·73	17·20	88·21
5		21st „ „	13·02	80·52	14·41	83·21	16·66	88·42	17·37	89·82	17·86	90·37	17·78	88·62	17·98	90·24
6		25th „ „	12·83	79·56	14·73	83·95	16·75	87·80	17·31	88·97	17·98	90·87	17·07	87·88	17·56	88·99
7		29th „ „	12·22	78·84	14·42	83·67	16·75	87·96	17·22	88·91	18·12	90·79	17·96	88·58	17·16	88·58
8		3rd May „	13·27	81·39	14·42	82·87	16·52	87·70	17·40	90·99	18·44	90·44	17·07	87·35	17·81	89·43
9		7th „ „	12·63	77·49	13·42	82·96	16·28	88·50	17·18	90·08	17·94	89·97	17·36	87·05	17·73	88·82
10		11th „ „			14·25	82·73	16·77	87·66	17·65	90·14	17·69	91·10	17·64	88·72	15·54	83·28
11		15th „ „			13·86	82·67	17·13	87·94	16·91	88·88	17·93	90·27	17·05	87·06	17·65	89·32
12		19th „ „			13·61	81·23	17·05	88·18	17·44	89·98	17·60	89·89	17·59	88·00	15·81	86·60
13		23rd „ „			12·73	78·13	16·82	87·79	17·39	89·36	..	..				
14		28th „ „			13·68	81·24	16·46	86·84	16·96	89·00	17·64	90·20				
		1942-1943														
1	Mother shoots.	22nd March 1942	12·26	77·78	14·79	82·62	16·09	85·07	16·45	87·20	17·34	89·89	16·01	86·78	14·89	84·92
2		24th „ „	11·93	76·17	15·78	86·22	17·07	89·13	17·10	88·33	17·54	88·61	17·30	89·13	16·34	88·33
3		26th „ „	12·80	78·23	15·78	86·22	16·11	88·26	18·03	91·09	17·83	90·07	16·77	88·20	17·06	89·13
4		19th April „	13·05	79·00	15·22	84·29	16·83	89·49	18·06	90·49	17·36	89·03	17·47	89·30	16·37	89·03
5	Tillers.	23rd „ „	13·03	79·92	15·18	84·85	16·31	88·12	17·50	89·34	18·19	89·80	16·89	88·73	16·32	88·76
6		27th „ „	12·42	78·27	14·99	84·34	16·82	90·00	17·30	88·75	18·01	89·25	17·38	89·17	16·83	89·60
7		1st May „	11·84	76·72	14·02	82·43	15·51	87·53	17·56	89·25	17·80	88·44	16·33	87·65	16·68	89·16
8		5th „ „	14·42	78·74	13·83	81·95	16·50	88·35	16·72	87·67	18·82	88·02	16·56	88·24	16·94	90·56
9		9th „ „							16·84	88·25	17·17	87·06				
10		13th „ „							16·89	86·97						
11		17th „ „							15·90	85·67						
12		21st „ „							17·55	90·29						

These figures do not suggest any particular trend in the quality of juices. Even Arceneaux [1935] observed very slight differences in indicated yield of sugar per ton of cane between mother stalks marked on 11 April and suckers of the two older groups marked on 20 April and 29 May respectively. Locsin [1936] reported that stalks of various orders, up to the 5th, came to maturity at about the same time although their start in light is several months apart. In this experiment the maximum age difference between the shoots, whose juice was analysed, was only about two months. This confirms the findings of Varahalu [1936] who said 'it is not only the age but more potent than this in controlling the performance and the maturity of a cane are the seasons of the year through which the crop passes during its stand, the order in which it faces several seasons and the duration of its stay in each one of them'. Shoots which arose by about the end of March as also those which originated by about the end of May together passed through the 'boom' stage (June to October) when there is maximum vegetative development as well as the succeeding winter months, when growth is arrested, and the concentration of cane juices increases. Hence perhaps, there was no marked difference in the quality of juices from the different shoots which were analysed in this experiment.

Summary

Several factors affect yield of sugarcane. Age of crop is one such. Its relationship with tillering, arrowing and the juice quality of different shoots, under normal conditions of manuring and irrigation was studied at Anakapalle during three consecutive seasons, 1940-1941, 1941-1942 and 1942-1943. The variety under trial was Co421.

The following conclusions are drawn:

(1) When plantings are done by about the 10th of March, active tillering phase begins by about the third week of April and extends till the end of May.

(2) The minimum period of growth for a shoot to produce a tiller is four days.

(3) Greatest number of successful tillers originate before the end of May. Hence manuring and other operations designed to improve tillering in this variety will have to be finished earlier than this month. Very few tillers usually arise from June onwards and they can be removed.

(4) Mortality of mother shoots due to borer attack is less than in tillers.

(5) Age of shoot and arrowing are positively correlated.

(6) There is no appreciable difference in the juice quality of shoots which come up till about the end of May. The maturity of all the stalks at harvest time will more or less be uniform if all of them originated before the end of May.

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APPENDIX

Meteorological data—Anakapalle

Month	1940					1941					1942				
	Total rain fall	No. of rainy days.	Mean Max. temp.	Mean Min. temp.	Relative humidity	Total rain fall	No. of rainy days	Mean Max. temp.	Mean Min. temp.	Relative humidity	Total rain fall	No. of rainy days	Mean Max. temp.	Mea n Min. temp.	Relative humidity
January	..	..	..	..	..	..	..	87·0	64·5	78·9	..	..	85·34	63·45	73·94
February	..	..	..	..	..	2·17	2	88·4	66·8	77·4	..	..	89·17	66·33	77·86
March	4·55	9	89·23	72·52	81·53	0·73	2	94·35	72·11	79·9	..	..	93·96	71·55	78·61
April	0·31	1	96·79	75·59	72·42	0·02	1	97·92	78·72	70·2	0·34	1	95·72	77·26	71·62
May	9·79	10	95·63	79·33	76·44	4·38	9	98·15	80·07	71·6	0·44	3	101·06	82·17	64·11
June	5·29	17	92·59	78·72	80·65	3·52	14	94·26	80·05	70·4	3·36	6	97·73	82·42	71·80
July	3·69	16	89·55	77·55	78·61	2·50	15	94·30	78·44	77·65	2·30	13	91·56	78·91	77·66
August	4·11	15	90·20	76·90	82·26	4·05	15	94·47	78·07	78·94	6·07	10	92·96	77·92	76·45
September	6·73	15	92·25	76·49	79·48	5·57	15	92·24	77·11	85·13	4·69	15	91·15	77·29	84·00
October	5·10	7	89·85	74·45	82·47	13·98	10	89·35	74·70	83·77	7·15	12	88·10	73·41	71·70
November	1·08	5	87·77	70·69	74·23	5·63	6	84·42	66·65	72·88	3·35	6	85·00	69·09	73·03
December	0·03	1	85·80	65·30	73·50	..	..	84·78	67·13	77·90	0·38	1	82·16	65·08	78·80
		1943													
January	0·98	3	84·72	64·75	82·61										
February	0·20	2	83·35	63·17	74·40										
March	..	..	93·50	69·10	74·20										
April	3·79	8	97·65	75·58	78·80										

INFLUENCE OF SOIL MOISTURE ON THE YIELD OF PADDY

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(With Plates XVII & XVIII and two text-figures)

RICE is the main staple crop in Bengal. It is grown all over the province under varieties of conditions which vary from water standing several feet deep on the field, in the case of the deep water paddy, to only moist soil in the case of *Aus* paddy which is generally grown in comparatively highlands where flood water does not generally get entrance or rain water cannot accumulate. When grown in low lying areas it is harvested before the entrance of flood water.

Briggs and Shantz [1914] found a high figure for water requirments of rice plants. The work carried out by the Agriculture Department, Bengal [1925-26], shows that the addition of phosphate to the soil reduces the water requirement.

Sherrard [1920] has shown that draining the rice fields at certain stages to be replaced by fresh water is beneficial to the crop. Singh and singh [1935] found that the transpiration ratio for rice plants is 519 which is quite in agreement with the figure obtained by Briggs and Shantz.

Sen [1937] published the results of an investigation on the water relation of rice plants. Three water conditions of the field were employed, viz. the water standing three inches deep, wet soil and cracked condition. Their effects were studied singly and in combination with one another and it was shown that standing water for about three weeks immediately after transplantation both in the cases of *aus* and *amon* paddy followed by de-watering is beneficial to the plant. Flowering is adversely affected by standing water. His investigations suffer from the lack of informations regarding the exact moisture conditions of the soil beyond the three stages mentioned above.

Although a good deal of work on the subject have seen the light, no systematic investigation on the water relation of rice plants in term of soil moisture, calculated purely on scientific basis, has yet been done. The present investigation was undertaken with the object of seeing how different doses of water applied at different intervals of time influence the growth and ultimately the seed formation of paddy or in other words the experiment was designed to find out the minimum moisture content of soil for *aus* paddy and where irrigation is possible what should be the quantity and interval between the successive periods.

The experiment was conducted with *aus* paddy which does not require any standing water in the field or any water logging but prefers moist soil. This is the autumn paddy in Bengal and is generally grown in the highland tracts and its life cycle is completed in 80-90 days. The sowing time is generally the months of March and April when the rainfall is not very frequent. So during the early stages of growth the land usually dries up to such an extent as to cause permanent wilting of the plants, resulting in either total failure of the crop or abnormally low yield.

The experiment was conducted in the pot culture house so as to obtain strictly controlled condition. The soil used in this experiment was the red soil of the Madhupur Jungle tract as represented by the Dacca Farm. (Physico-chemical properties of this soil will be described elsewhere.)

In this experiment the soil was kept under three moisture conditions, viz.

(1) 75 per cent of the maximum saturation capacity.
(2) 50 per cent ,, ,, ,,
(3) 33 per cent ,, ,, ,,

All these soils were allowed to dry for some definite periods after each addition of water. Thus although the pots were initially brought to a definite percentage of saturation they did not remain so throughout the whole period but lost considerable moisture which was recouped after fresh additions of water after definite intervals of time varying from 3 to 21 days. The loss of moisture from the pots were due to two causes (i) evaporation from the soil, and (ii) transpiration through the leaves. The loss due to the former cause will result in unequal distribution of moisture in the soil in the pot

which is not desirable in an experiment like this. Therefore the loss due to evaporation was reduced to a minimum by tightly covering the pots with rubber cloth.

The soil was thoroughly mixed with cowdung at the rate of 200 gm. of cowdung per 13 kilos of soil. The manured soil was then gradually packed in tin pots (10 in. ×10 in.×10 in.). Before introducing the soil a perforated earthen pot was placed in an inverted position at the bottom of each tin pot. This perforated earthen pot served as an air chamber to facilitate root respiration. A glass tube about ¼ in. in diameter was introduced in the tin pot through an opening in the wall of the pot and finally let into the inverted earthen pot. Thus the interior of the air chamber was in direct communication with the outside air. Calculated quantity of water necessary to bring the soil to the requisite percentage was sprinkled over the soil. After each addition the soil was thoroughly mixed so that water may be uniformly distributed in the soil. The pots were then kept over night to ensure absorption of water by soil. *Aus* paddy seedlings about three weeks old was transplanted one in each pot. The open faces of the pots were tightly covered with rubber cloth which had a perforation at the centre through which the plants were let out. The opening round the plant was plugged with cotton so that there may not be any loss of moisture due to evaporation. In spite of these precautions certain amount of water evaporated off which was indicated by the loss of weight in the control pots which were similarly treated but no plants were put in. The reason for adopting such a drastic measure to check the loss of moisture due to evaporation is that the evaporation will cause unequal distribution of moisture in the soil—the top soil will be more affected than the soil occupying the lower layers. This sort of unequal distribution of moisture is most objectionable in such an experiment.

The selection of seedlings presented some difficulty. It has already been mentioned that only one seedling was put in each pot so that uniformity of seedlings is essential. Utmost care was taken in selecting plants of equal strength and growth. The selection was based on the number of leaves, the thickness of the stem, the height, etc. After transplantation the pots were kept in a shady place for three or four days in order that the plants may easily take roots. Any plant which showed abnormal growth was replaced by a normal one. Generally it was found that there is hardly any necessity of replacement.

The real experiment was started after 10 days from the day of transplantation when the pots were all weighed and brought to the required saturation by the addition of water where necessary. Thus before starting the experiment, the soil in all the pots of the first series had 33 per cent saturation, second 50 per cent and the third 75 per cent.

The pots in each of the three series were divided into seven groups, each group containing 4 pots, and one group from each series was watered after a definite interval of time. The arrangements of the pots in series and groups and the watering periods are shown in Table I.

TABLE I

Arrangement of pots in series and groups and the watering periods

Particulars	33 per cent saturation 1st series	50 per cent saturation 2nd series	75 per cent saturation 3rd series	Period of watering
	No. of pots	No. of pots	No. of pots	
First group	4	4	4	Every 4th day
Second group	4	4	4	,, 7th day
Third group	4	4	4	,, 10th day
Fourth group	4	4	4	,, 13th day
Fifth group	4	4	4	,, 16th day
Sixth group	4	4	4	,, 19th day
Seventh group	4	4	4	,, 22nd day

As regards the 4th series, 4 pots had 20 per cent saturation and 4 pots 25 per cent saturation and another 4 pots had 33 per cent saturation.

All the pots in the 4th series were watered every day to bring them to the initial saturation.

The pots were placed on trollies and exposed to sun and light during the day but were carefully protected from rain. The loss of moisture from the pots was thus wholly due to transpiration and

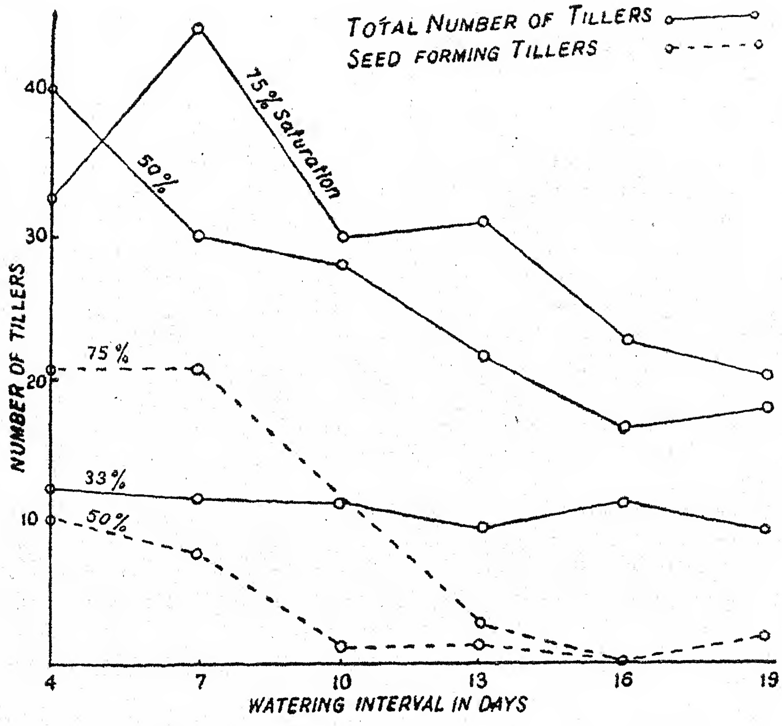


FIG. 1. Saturation and number of tillers

building up of the tissues. The loss due to evaporation from the control pots was negligible in comparison with the loss due to other causes. In no case did the daily loss from the control pots exceed 20 c.c. of water per day. The average daily loss in the control pots was 10 c.c. per day.

All the pots in the 4th series were daily weighed and watered to the initial saturation while the pots of the other series were weighed after the intervals shown in Table I and water added to each pot to bring them to the same water content which they had at the beginning. Thus the pots of the three series were subjected to a drought varying from 2 to 20 days. None of the plants suffered much during the early period of growth when the water requirements were very small but the plants of the 33 per cent saturation series totally lost their potentialities during the latter period even after a lack of water for 2 days as was manifest from their failure to form seed.

The plants of the other series could more or less resist drought up to a maximum of 12 days but the yield was so poor that they may be regarded as total failures.

Fig. 1 shows that none of the pots of 33 per cent saturation formed seeds though some of them flowered, while most of the plants in the other series flowered but those which were subjected to a drought of more than 10 days did not form seed. Groups 1, 2 and 3 of the second and third series formed seed showing that water is essentially necessary during the flowering stage for seed formation.

It will be seen from the Figs. 1 and 2 that in 75 per cent saturation series the number of tillers and the yield of straw jump up in the second group with six days watering interval and then gradually fall down as the interval of watering is increased while in the case of 50 per cent saturation both the number of tillers and the yield of straw fall down systematically with the increase in the watering interval. In 33 per cent saturation the crop is practically a failure one and the watering interval has no appreciable effect either on the tillering or on the yield of straw.

Another interesting feature brought to light in course of this experiment is that there are critical stages in the growth of the plants when absence of sufficient water causes total damage to the crop.

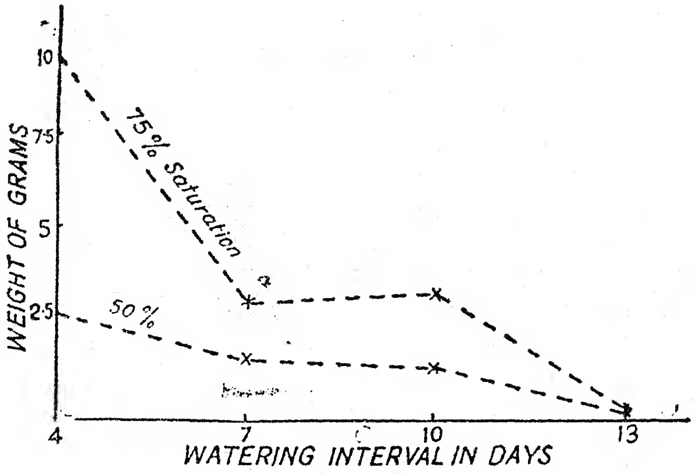


FIG. 2. Saturation and seed formation

Externally the plants wilt and if this wilting continues for some time, some of the more tender parts specially the root hairs are destroyed. The result is that it checks the development of flower buds and the formation of seeds. In the fourth series of pots, which were watered daily, there was a progressive improvement in growth as the saturation increased (Plate XVII). The plants which were kept at 20 per cent saturation, i.e. at 9·2 per cent moisture content, a value slightly above the wilting point of soil though showed healthy growth, did not flower with exception of one.

Plants at 25 per cent saturation formed seed but not as good as the plants in 33 per cent saturation.

The seed formation at 33 per cent saturation, watered daily, was as good as 75 per cent saturation watered every fourth day. The vegetative growth was best in 75 per cent saturation watered every seventh day but was not as good as fourth day group in seed formation (Figs. 1 and 2).

TABLE II

Analysis of variance—straw

Particulars	Degree of freedom	Sum of squares	Mean squares	S.D.
Interval	5	447·17	74·53	
Per cent saturation	2	1951·44	975·72	
Interaction	12	159·96	13·33	
	20	2558·57		
Residual	63	227·90	3·62	1·903
Total	83	2786·47		

S.E.=1·903

TABLE III

Analysis of variance—tillers

Particulars	Degree of freedom	Sum of squares	Mean squares	S.D.
Interval	6	2432	405·3	
Per cent saturation	2	4781	2390·5	
Interaction	12	1450	120·8	
	20	8636		
Residual	63	2027	32·17	5·67
Total	83	10690		
		S.E.=5·67		

TABLE IV

Height of the plants

Particulars	Degree of freedom	Sum of squares	Mean squares	S.D.
Interval	6	540·96	90·16	
Per cent saturation	2	1365·09	682·54	
Interaction	12	67·62	5·63	
	20	1973·67		
Residual	63	410·20	6·51	2·55
Total	83	2383·87		
		S.E.=2·55		

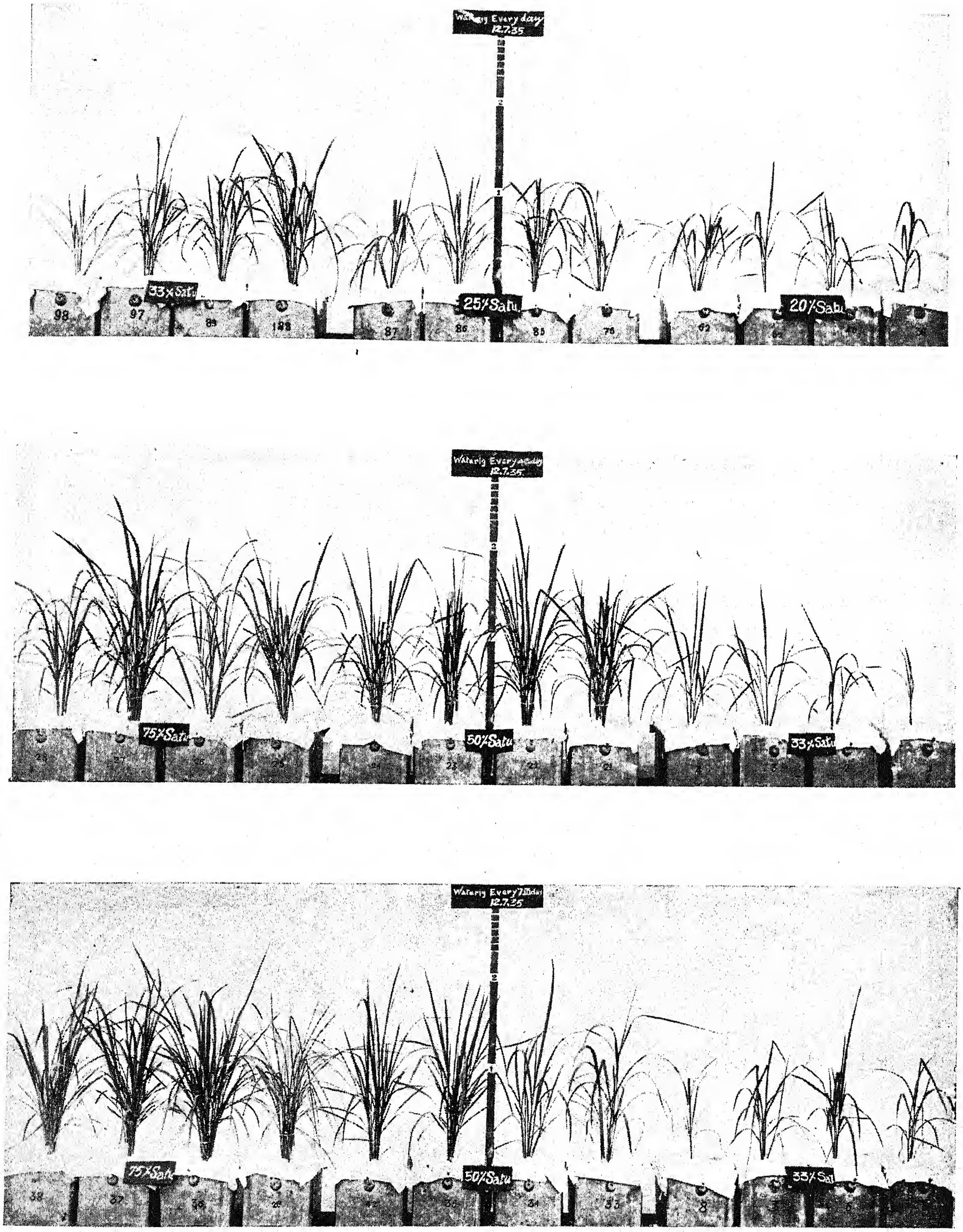
On examining the results in the above analyses it will be found that the effect of percentage difference in saturation is more pronounced in height, tillering and in the yield of straw than the interval though highly significant improvement is noticed as the interval is decreased in the same saturation. The most striking point is that every seventh day watering group of 75 per cent saturation series recorded the highest yield in straw and better than every fourth day watering group of the same series, while the yield of grain has been much better in every fourth day watering group, indicates that with 75 per cent saturation, watering every fourth day during the early stage of growth is detrimental to tillering but essential for seed formation.

A photographic examination of the plants (Plate XVIII) shows that on 12th July 1935 every fourth day watering group of 50 per cent saturation is better than the same group of 75 per cent series. But the final photographs taken immediately before harvest (Plate XVIII) show that all the groups of 75 per cent saturation are decidedly better than the respective groups of the other series.

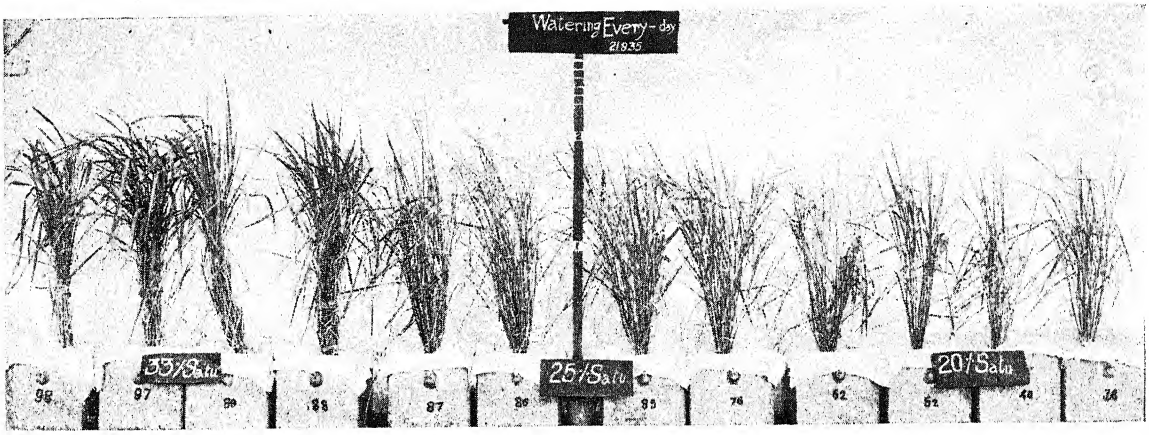
SUMMARY

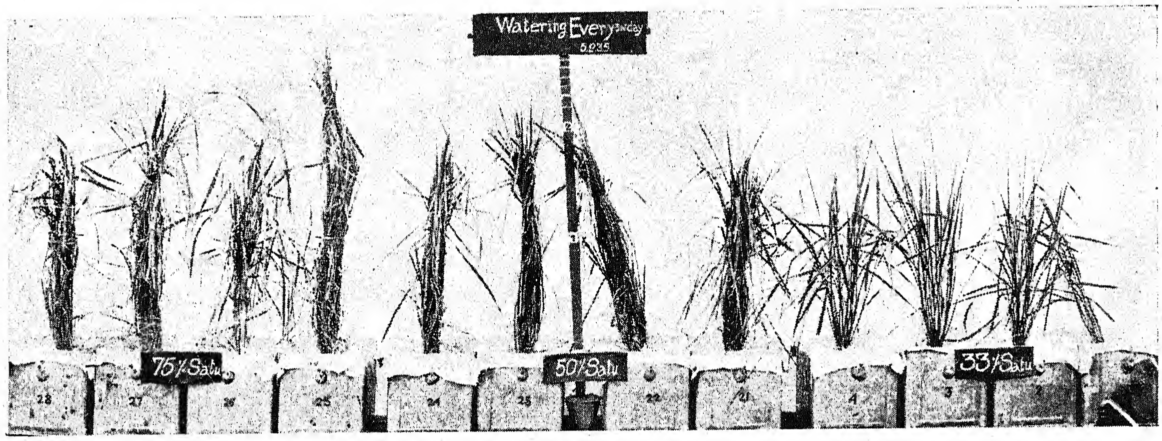
The water requirements of rice plants in terms of soil moisture has been investigated. The experiment was conducted in the pot culture house. The soil was initially kept in three moisture conditions called series

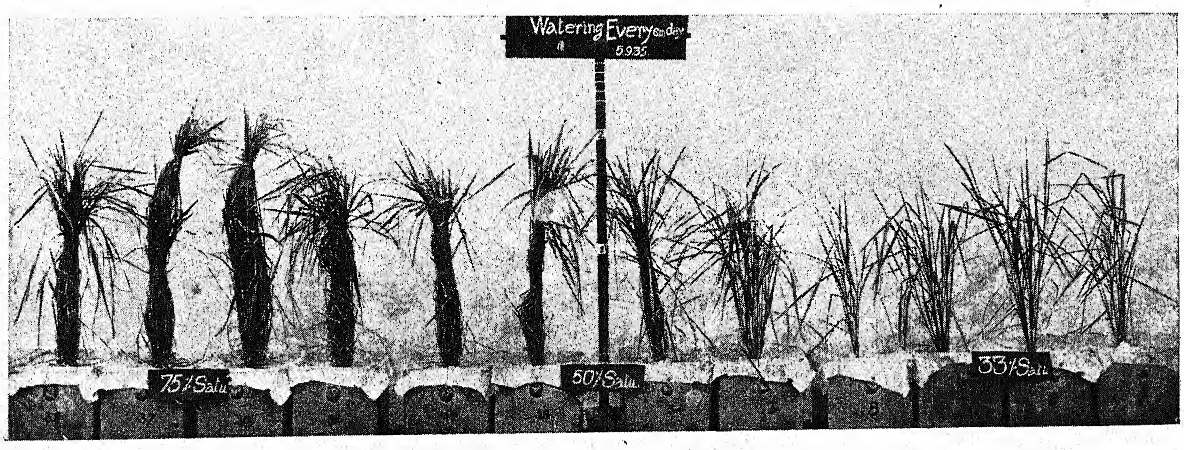
(1) 33 per cent of the soil saturation capacity
(2) 50 per cent ,, ,, ,,
(3) 75 per cent ,, ,, ,,



Effect of watering on the growth of paddy. *Top:* Watering every day. *Centre:* Watering every 4th day. *Below:* Watering every 7th day







Effect of watering on the growth of paddy. *Top:* Watering every day. *Centre:* Watering every 3rd day. *Below:* Watering every 6th day

Each series was sub-divided into seven groups and each group was watered after intervals of 3 days, 6 days, 9 days, and so on up to 21 days.

It has been found that during the early stages of growth the plants were not much affected by the interval of watering. But during the latter stages they were so affected as to result in a total failure of the crop. Thus the plants could not stand watering at the interval of 3 days, 6 days, and 9 days in the cases of 33 per cent, 50 per cent and 75 per cent saturations respectively.

In the case of the 75 per cent saturation series, every seventh day watering group recorded higher yield in straw than every fourth day watering group of the same series, while the yield of the grain was better in every fourth day watering group of 75 per cent saturation series. The conclusion is that excessive water at the early stages of growth of paddy is detrimental to tillering but essential for seed formation. Further the effect of percentage difference from series to series is not so pronounced as that of the interval.

ACKNOWLEDGEMENT

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SOILS OF BENGAL AND THEIR PHYSICO-CHEMICAL CLASSIFICATION

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(With four text-figures)

BENGAL is intersected by a net work of rivers and channels which derive their origin from different sources and pass through different tracts before entering Bengal. They naturally carry deposits of quite different character and composition. The soils of the province are, therefore, greatly influenced by these rivers. Apart from the river alluvium a considerable portion of the province is occupied by sedentary soil. A broad classification of the soils on the basis of their physico-chemical characteristics has been attempted here.

The soils of the province can thus be broadly put into two great divisions, the alluvial and the sedentary. The bulk of the soil of the province is alluvial while sedentary soils can be found only in the districts of Bankura, Birbhum, Midnapore, Burdwan, Jalpaiguri and Darjeeling. In these parts of the province the rock materials of which the soil is formed are still undergoing transformation. In some places the top few feet are covered with a culturable soil while below it undecomposed rocky strata can be found.

The alluvial soil of the Province can again be divided into two groups, the red soil and the new alluvial soil. Apart from the physical and chemical characteristics, the red soil is distinguished from the new alluvial soil by the characteristic red colour. The Madhupur Jungle tract of East Bengal and the Barind tract of North Bengal form the bulk of this red soil. The rest of the province

is under the new alluvial soil. The area covered by the new alluvial soil is much greater than the area covered by the other two, the red soils and the sedentary soils. These are the main outlines of the principal soil divisions of the presidency.

The red soil represent a type of sandy loam with increasing percentage of clay in the lower horizon. They are very poor in organic matter and are highly acid in reaction. The chemical composition shows that they are poor in lime and phosphoric acid but moderately rich in potash (Table I).

The sedentary soils of the Burdwan Division which are also deficient in lime and phosphoric acid differ widely in physical characteristics from the red soils of the Madhupur Jungle tract. These soils are full of gravels of various sizes and shapes which are still undergoing further disintegration. The surface soil is full of concretionery materials and in some places the concretions have attained such a development as to preclude the growth of vegetation.

The new alluvial soils represent the largest and the most important soil divisions of the Province. They vary from fairly coarse sand on the *chars* (island in rivers) and on the banks of the rivers to soils of very close texture on the low lying (marshes) tracts. The new alluvial soils are generally very rich in plant food and grow all sorts of crops.

List of soils used

METHODS EMPLOYED

Sample No.	Locality	Description
Ps. 10	Barisal	Grey with white tint. New alluvial soil of recent origin
Ps. 16	Nadia	Grey, New alluvial soil (Gangetic)
Ps. 17	Bankura	Laterite soil, Sedentary. Red with brown tint
Ps. 18	Burdwan	Deep brown with reddish tint, Laterite soil
Ps. 19	Dacca Madhupur Jungle tract	Red with yellow tint, alluvial soil, highland
Ps. 20	Dacca	Grey. New alluvial soil
Ps. 21	Dacca Madhupur Jungle tract	Reddish brown, alluvial soil, lowland
Ps. 22	Rangpur	Grey, with ashy tint, mixed with micaceous flakes, Teesta silt
Ps. 23	Rajshahi	Grey, new alluvial soil, Ganges silt
Ps. 24	Dinajpur	Grey, new alluvial soil
Ps. 25	Chittagong	Grey with white tint, alluvial deposit at the extreme end of the Sitakund Hills
Ps. 26	Midnapore	Brown with yellow tint, laterite soil
Ps. 27	Mritadaspur (Birbhum district)	Brown with yellow tint, laterite soil, Sedentary
Ps. 14	Birbhum	Brown with yellow tint, laterite soil, Sedentary

The soil samples were prepared by passing through 1 mm. sieve with round holes.

Loss on ignition. About 10 gm. of air dry soil was ignited in a platinum basin over a bunsen flame until constant weight was obtained.

Mechanical analysis. Clay and silt was determined by international method.

Moisture holding capacity was determined by Keen and Raczkowski method [1921] as modified by Coutts [1930].

Moisture content at half saturation was determined by Keen and Coutts [1928] methods.

Chemical analysis was done by the Standard A.O.A.C. method.

TABLE I

Chemical analysis of soils—Laterite and red soil group

Name of soils	Insoluble residue percentage	K_2O total percentage	CaO total percentage	MgO total percentage	P_2O_5 total percentage	Nitrogen percentage
Ps. 14	93·86	0·26	0·11	0·12	0·036	0·036
Ps. 17	81·19	0·26	0·37	..	0·028	0·032
Ps. 18	84·34	0·58	0·47	0·67	0·029	0·042
Ps. 19	83·93	0·75	0·16	0·35	0·058	0·084
Ps. 21	84·58	0·71	0·098	0·31	0·047	0·11
Ps. 26	90·15	0·272	0·202	0·152	0·018	0·046
Other group						
Ps. 10	76·95	1·01	2·20	1·97	0·14	0·110
Ps. 16	85·83	0·915	0·579	0·85	0·249	0·063
Ps. 20	79·95	0·98	1·35	1·94	0·128	0·036
Ps. 22	79·50	1·18	0·26	1·77	0·103	0·106
Ps. 23	71·80	1·41	2·97	2·11	0·128	0·105
Ps. 24	81·83	0·779	0·279	1·133	0·083	0·039

TABLE II

Composition of the clay fraction—Laterite and red soil group

—	Silica	Fe_2O_3	Al_2O_3	SiO_2/Al_2O_3	SiO_2/R_2O_3
Dacca (H) (Ps. 19)	39·60	9·00	25·33	2·60	2·162
Suri (Ps. 14)	44·91	11·37	25·35	3·00	2·336
Bankura (Ps. 17)	44·73	12·70	26·35	2·88	2·203
Burdwan (Ps. 18)	45·27	11·76	23·04	3·30	2·515
Dacca (Low) (Ps. 21)	39·30	7·44	27·935	2·40	2·040
Midnapur (Ps. 26)	38·26	11·03	29·12	2·20	1·795
Other group					
Barisal (Ps. 10)	44·60	14·19	22·385	3·37	2·405
Rangpur (Ps. 22)	39·52	12·39	26·735	2·48	1·936
Rajshahi (Ps. 23)	43·08	14·74	22·95	3·57	2·258
Dacca (silt) (Ps. 20)	48·32	11·19	25·06	3·27	2·546
Nadia (Ps. 16)	44·14	12·66	24·09	3·11	2·328
Dinajpur (Ps. 24)	38·44	11·46	27·12	2·40	1·893

The chemical analysis in Table I shows that the soils of the so-called laterite and red soil group are poorer than the soils of the other group in all the constituents particularly in phosphoric acid and potash. The nitrogen figures in general are also lower in the 1st group than that in the other group. Ps. 21 which is a low land soil is however a solitary exception in the 1st group.

It was expected that the composition of the clay fraction would give a valuable information as to the nature of the soils and would thereby furnish a dependable basis of classification. But it is practically of no value in this particular case. The figures for silica/alumina ratio in Table II is rather misleading. The ratios in all cases is above 2·00. Therefore according to the definition of Martin and Doyne [1930] none of the soils fall under the group ' laterite '. At any rate these soils form a group themselves and are quite different from the soils of the other group and are more akin to the laterite soils. In absence of any morphological study no definite conclusion is possible at this stage.

A scrutiny of the figures in Table II, however, shows that the Silica/Allumina ratio of the non-laterite group is slightly higher. But no sharp line of demarkation is possible. The Fe_2O_3 figures in the so-called laterite group is definitely lower than those in the non-laterite group. This does not however mean much in the matter of classification.

TABLE III

Mechanical analysis—Laterite and red soil group

Sample No.	Clay	Silt
Ps. 14	9·00	..
Ps. 17	20·35	7·45
Ps. 18	13·13	12·22
Ps. 19	23·90	27·62
Ps. 21	27·05	34·80
Ps. 26	14·45	23·55
Ps. 27	19·90	21·25
Other group		
Ps. 10	18·60	38·00
Ps. 16	15·50	29·10
Ps. 20	21·25	58·05
Ps. 22	11·55	23·50
Ps. 23	18·70	33·62
Ps. 24	16·10	27·95
Ps. 25	12·75	42·75

TABLE IV

Results of physical measurements—Laterite and red soil group

Soil No.	Loss on ignition	Percentage of moisture at 50 per cent humidity	Apparent sp. gr.	Percentage of water holding capacity	Percentage of pore space	Real sp. gr.	Percentage of volume expansion	Percentage of sticky point moisture
Ps. 14	1·54	0·07	1·57	28·30	41·50	2·50	4·90	12·10
Ps. 17	3·56	0·54	1·41	31·45	42·15	2·31	6·13	15·10
Ps. 18	3·39	0·87	1·20	39·50	46·70	2·31	11·40	20·04
Ps. 19	4·29	1·15	1·28	46·60	52·00	2·43	8·56	28·43
Ps. 21	4·42	1·26	1·24	54·20	56·70	2·42	12·97	29·75
Ps. 26	3·16	..	1·47	32·91	42·20	2·28	9·70	16·50
Ps. 27	2·37	..	1·51	28·12	40·20	2·39	6·30	15·60
Other group								
Ps. 10	3·67	1·12	1·14	56·60	56·29	2·35	10·35	29·33
Ps. 16	1·97	0·59	1·32	49·20	56·80	2·20	10·50	25·18
Ps. 20	3·58	1·69	1·09	60·41	57·53	2·23	12·11	37·00
Ps. 22	4·30	0·89	1·16	51·95	54·89	2·36	6·50	29·70
Ps. 23	4·98	1·67	1·07	61·50	59·61	2·42	8·25	25·06
Ps. 24	4·44	..	1·32	46·37	53·88	2·52	8·50	25·25
Ps. 25	3·61	..	1·28	44·12	55·84	2·86	8·26	27·81

Soil exhibits certain characteristic physico-chemical behaviour specially when associated with water. A detailed study of the physical properties of the moist soil was, therefore, initiated with a view to elucidate the general character of these soils by a quantitative assessment of one property or a group of properties.

Mechanical analysis, however, furnishes a valuable information regarding the make up of the soil but such data do not provide any basis of specification. The soil character is not influenced so much by the size of the different particles, of which the soil is made up, as by their inherent character. The latter influences the moisture relationship to such an extent that this relation serves as a valuable guide for the proper specification of the soil.

Keen and Coutts [1928] stressed the importance of specifying the soil by a single number and introduced the term 'single value soil constant' and such methods were given the name 'single value determination'. These authors critically examined some of the values such as the moisture

content at 50 per cent relative humidity (R), loss on ignition (I), and sticky point moisture (S) against the clay fraction (C). The correlations between the different constants were worked out by Fisher's method and they obtained definitely significant cœfficients. Their figures are given below:

—	Original soil			—	Peroxide treated soil		
	I	R	S		I	R	S
C	0·364	0·719	0·317	C	0·662	0·760	0·675
I	..	0·388	0·865	I	..	0·386	0·879
R	..	..	0·503	R	..	..	0·584

The highest figures were obtained in the case of C and R and also in the case of S and I.

They also calculated the partial correlation between C and R where I was eliminated and between S and I where C was eliminated and concluded that the value of the sticky point is largely controlled by the material in the soil that is driven off by ignition while the moisture content at half vapour pressure is controlled more by the clay content. Sen and Deb [1941] from a similar study of the Indian laterite and red soils observed that the moisture content at half saturation and the stickly point are largely controlled by the material in the soil that is driven off by ignition.

The figures in Table IV show that the new alluvial soils of Bengal have higher moisture holding capacity and higher sticky point moisture and retain more moisture at half saturation than the laterite and the red soils having the same clay content. The volume expansion on swelling is also higher in the case of the new alluvial soils than the soils of the other group. Similar observations were made by Hardy [1923] who found comparatively low sticky point for soils having low silica/alumina ratio. The same author [1925] also reported low swelling coefficients for the laterite soils of Barbados and Dominica. Marchand and Van der Merwe [1926] obtained similar results in the case of the Transvaal soils.

For a proper understanding of the character of the soils of Bengal a comparative study of some of the physical constants such as the water holding capacity (m), pore space (p), sticky point moisture (s), volume expansion (v) in Table IV, on the one hand and the clay content (c) on the other has been made.

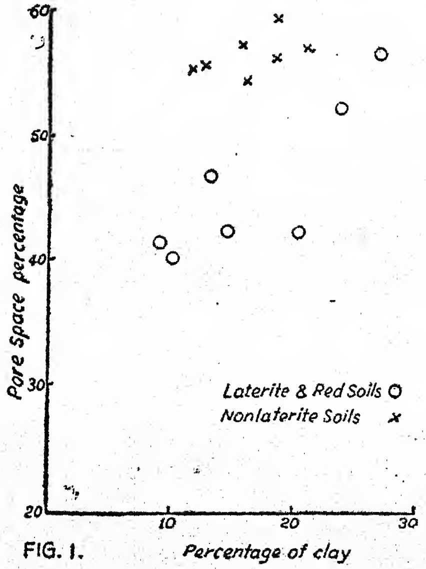

FIG. 1.

FIG. 1. Scatter diagram of soils

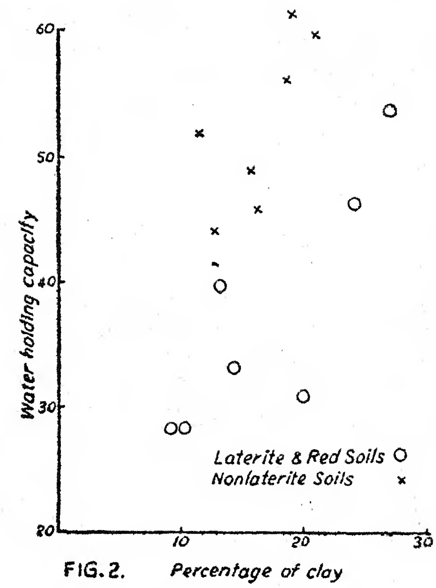

FIG. 2. Scatter diagram of soils

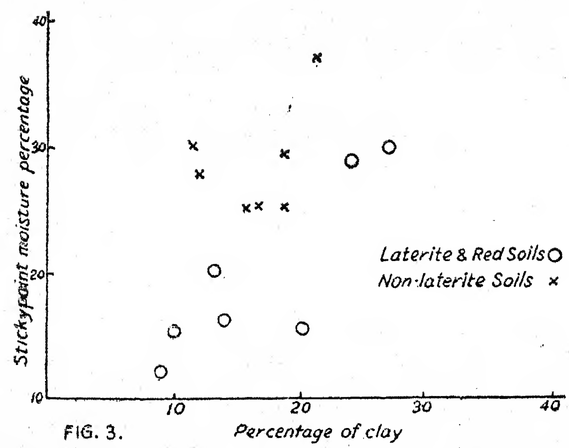

FIG. 3. Scatter diagram of soils

The correlation coefficients are given below ;

Cm=0·525.
Cp=0·434.
Cs=0·507.
Cv=0·651.

It is clear from the above figures that the clay content of the Bengal soils bears no relation with any of the constants. Keen and Raczkowski [1921] found that these constants are linearly related with the clay content. Keen and Coutts [1928] report high correlation coefficient for a number of British soils. Marchand [1924] and Coutts [1929] in the case of the Transvaal and Natal soils respectively found high correlation coefficient between the above values. The red soils and the Indian laterite soils also show high correlation coefficient between the above values except in the

case of volume expansion [Sen and Deb 1941]. These authors could not discover any relation between the volume expansion and the clay content.

The absence of any association between any of the above values and the clay content in the case of the Bengal soils led the author to examine the values in more detail. Each of the values were plotted against the clay content for further scrutiny. It may be seen from the scatter diagrams in Figs. 1-4 that the soils examined here fall under two different groups. The laterite and the red soils fall under one group and the rest, i.e. the non-laterite or rather the new alluvial soils, in another. The values in each group are associated with the clay content. It therefore suggests that these soils deserve to be examined separately and cannot be pooled up together. These associations

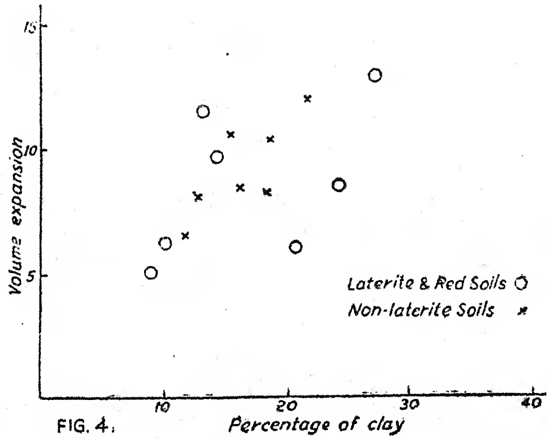

FIG. 4.

Fig. 4. Scatter diagram of soils

between the different values and the clay content when expressed in terms of correlation co-efficient for each group give the following values :

—	Laterite and red soil group	Non-laterite group
rcm	0·950	0·750
rcp	0·874	0·582
rcs	0·868	0·404
rcv	0·648	0·775

It will be seen from the above that the correlation coefficient in the case of the laterite and the red soils are significant at 1 per cent level in all cases except in the case of the volume expansion. In the other group, however, significant values are obtained only in the case of moisture holding capacity and volume expansion and that too just at 5 per cent level of significance.

The regression equations are :

$$\left.\begin{array}{l} c=0{\cdot}649\ m-6{\cdot}78 \\ c=0{\cdot}951\ p-25{\cdot}95 \end{array}\right\}\text{For soils of laterite group.}$$

$$\left.\begin{array}{l} c=0{\cdot}382\ m-3{\cdot}84 \\ c=1{\cdot}081\ p-44{\cdot}64 \end{array}\right\}\text{For non-laterite group.}$$

These values are different from what was obtained by Sen and Deb [1941], viz.

$$c=0{\cdot}9296\ m-8{\cdot}935.$$
$$c=1{\cdot}367\ p-32{\cdot}085.$$

They also report that in 30-40 per cent cases the relations break down. Similar observations were made by Marchand [1924]. The results obtained here show little difference between the observed and the calculated values.

SUMMARY

A physico-chemical classification of the soils of Bengal based on moisture relationship has been attempted. The classification suggests the possibility of grouping the soils under two heads, the laterite and the red soils falling under one head and the rest under the other. In each group certain properties can be correlated with the clay content of the soil. The results show that the heavy clay soils have the highest ignition losses, maximum water holding capacity and sticky point moisture. No correlation could be found between the volume expansion and the clay content. While in the non-laterite group significant correlation coefficient could be found in the case of the maximum moisture holding capacity and volume expansion.

ACKNOWLEDGEMENTS

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THE VERTICAL DISTRIBUTION OF PHOSPHATES IN CALCAREOUS SOILS

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(With one text-figure)

THE soil is not a homogeneous body of constant composition, being formed from the weathering of various rocks of different geological origin. It consists of several minerals intermixed in different proportions at different layers. Like every other soil constituent, its phosphate status is also likely to be variable. It is well known that plant roots forage in both surface soil and sub-soil, finding the phosphate in the latter as readily available as in the former. The greater portion of that entering the roots is deposited in the aerial parts of the plant, and later, on the decay of leaves and stems, is left on the surface. Each succeeding season will thus witness a new draft upon the phosphate of

the sub-soil without any return. Ramann [1911], however, noticed that the distribution of phosphate in successive horizontal soil layers is not governed by any universal rule. For example, Wohltmann [1901] found that the surface soil of western Germany is sometimes richer and some times poorer in phosphate than the corresponding sub-soil, and Kossowitsch [1912] noticed in the Chernozem soils of Russia that the phosphate content is somewhat higher in the first 4 to 8 in. than in the underlying layers. Similarly Hopkins [1910] and Brown [1914] found respectively in the prairie soils of Illinois and Iowa a higher percentage in the surface than in either the sub-surface or the sub-soil. Alway and Isham [1916], however, noticed in the loess soils of Nebraska that the proportion of phosphate is generally smaller in the first and the second foot than in the lower layers. On the other hand, Alway and Rost [1916] found that prairie loess soils of Nebraska in the surface foot show a steady decrease in phosphate from the surface inch downward, independent of the aridity of the climate in which they have formed. Peter [1916] draws attention to the peculiar distribution in the vertical sections of soil from the experiment station at Lexington and points out that it corresponds strikingly with the distribution of phosphate in the phosphatic limestone beds of this vicinity.

The manuring and cropping may also have some effect on the phosphate penetration in field soils. Stephenson and Chapman [1931], comparing soils receiving from 1 to 30 or more annual applications of a phosphate-carrying fertilizer with similar soils which had not received phosphate, showed appreciable penetration of the phosphate below the surface foot in light-textured to medium-textured soils, and little or no penetration in very heavy soils. Similarly Thor [1933] found that on the more compact soil there was definite downward movement of phosphate into 7 to 14 in. depth, but only a slight movement into 14 to 21 in. depth. On the other hand, Crawley [1902], on applying superphosphate, found that nearly the whole of the phosphoric acid remained within 6 in. of the surface and that more than half remained in the first inch of the soil. Van Alstine [1918] and several other workers too found that when phosphate is used as a fertilizer, it remains almost where it is placed in the soil until removed in crops or by some such process as erosion by water or wind action.

Calcareous soils of Pusa in Bihar are particularly deficient in readily available phosphate and respond to phosphate fertilization for proper crop production. It, therefore, became of interest to know the vertical distribution of phosphate in these soils and the effect of cropping and fertilizer practices on it. The work of Warington [1873], Cameron and Bell [1907], Basset [1917], De Jong [1926], Gassman [1928], Kramer and Shear [1928], and McGeorge and Breazeale [1931] shows that phosphorus is present in calcareous soils as calcium carbonato-phosphate or carbonato-apatite, a compound formed of three molecules of tricalcium phosphate and one molecule of calcium carbonate in which the calcium carbonate is an integral part of the complex molecule. The carbonato-phosphate must dissociate to enable the plant to absorb the phosphate ion. The dissociation of this compound is greatly reduced in the presence of the common ion calcium, and is still further reduced by the solid phase calcium carbonate in the presence of the calcium ion. This leads to the comparative unavailability of native calcium phosphate in calcareous soils here.

Experimental

In order to find out the distribution of phosphates in these soils, 3-inch soil borings down to a depth of five feet from some permanent manurial plots of the Chemical Section in Pusa calcareous soils (at the old site of the Imperial Agricultural Research Institute at Pusa) were taken to examine their total phosphate contents. These permanent manurial plots, 20 ft. by 25 ft. each, were laid out in 1920. Manure were applied to the plots once every year just before the monsoon. In these plots *ragi* (*Eleusine coracana*) was raised as *kharif* (summer) crop, followed by either wheat or oats as the *rabi* (winter) crop. Before the date of collecting soil borings in 1933, *ragi* was raised in these plots for 14 seasons, and wheat and oats for 2 and 11 seasons respectively. Phosphate and potash were applied as superphosphate and potassium sulphate respectively for 14 years. The results obtained are given in Table I with the $CaCO_3$ content of the corresponding soil layers. An adjacent fallow plot was also included in this study for comparison.

TABLE I

Total P_2O_5 and $CaCO_3$ contents of 3-inch soil sections of two permanent manurial plots and a fallow plot in Pusa calcareous soil

3-inch soil sections	Depth in inches	Fallow plot		Plot No. 8 P superphosphate		Plot No. 9 K potassium sulphate	
		Percentage $CaCO_3$	Percentage P_2O_5 in mg.	Percentage $CaCO_3$	Percentage P_2O_5 in mg.	Percentage $CaCO_3$	Percentage P_2O_5 in mg.
1	0—3	37·60	81·6	36·15	132·3	35·65	91·5
2	3—6	37·08	79·4	36·43	101·4	35·93	87·1
3	6—9	36·93	79·4	36·68	90·4	36·75	82·7
4	9—12	36·43	81·6	37·15	77·2	36·50	72·8
5	12—15	36·85	81·6	37·73	81·6	36·00	69·5
6	15—18	36·88	77·2	39·35	77·2	38·43	72·8
7	18—21	37·68	70·6	43·50	65·1	40·93	66·2
8	21—24	37·25	66·2	46·25	58·4	42·98	58·4
9	24—27	38·00	66·2	46·85	59·5	44·35	56·2
10	27—30	38·48	64·0	46·60	59·5	46·18	49·6
11	30—33	38·75	64·0	47·25	55·1	44·75	51·8
12	33—36	40·00	61·7	44·10	50·7	35·65	81·6
13	36—39	38·75	65·1	32·25	75·0	30·93	95·9
14	39—42	39·75	66·2	33·50	72·8	30·50	81·6
15	42—45	40·25	66·2	33·23	68·4	33·23	88·2
16	45—48	40·58	64·0	45·18	44·1	45·23	54·0
17	48—51	41·23	71·7	47·50	54·0	46·75	52·9
18	51—54	41·33	72·8	44·58	48·5	44·25	58·4
19	54—57	42·50	66·2	45·50	50·7	45·23	56·2
20	57—60	43·68	60·6	45·23	57·3	44·93	58·4

In order to get an approximate idea of the distribution of phosphate and its relation to the corresponding $CaCO_3$ contents at different depths the per cent average P_2O_5 and $CaCO_3$ per foot are stated in Table II.

TABLE II

Per cent average P_2O_5 and $CaCO_3$ per foot of the fallow and the two permanent manurial plots in Pusa calcareous soil

Depth	Fallow plot		Plot No. 8 P superphosphate		PLOT No. 9 K potassium sulphate	
	Percentage $CaCO_3$	Percentage P_2O_5 in mg.	Percentage $CaCO_3$	Percentage P_2O_5 in mg.	Percentage $CaCO_3$	Percentage P_2O_5 in mg.
1st foot	37·01	80·5	36·60	100·3	36·21	83·5
2nd "	37·17	73·9	41·71	70·6	39·59	66·7
3rd "	38·81	64·0	46·20	56·2	42·73	59·8
4th "	39·83	65·4	36·04	65·1	34·97	79·9
5th "	42·19	67·8	45·70	52·6	45·29	56·5

From Table II it is seen that in the fallow plot the P_2O_5 content varies almost inversely with the increase of $CaCO_3$ concentration and with depth. In the other two plots a similar relationship holds in the individual depths. In the fourth foot there exists a minimum $CaCO_3$ concentration

preceded and followed by maximum carbonate concentrations in third and fifth foot respectively. The corresponding P_2O_5 contents bear out the same inverse relation with $CaCO_3$ as in the fallow plot. The soil in the first foot of every plot contains the maximum phosphate concentration. The superphosphate plot was manured every year and consequently shows the highest P_2O_5 concentration in the surface foot, but the applied phosphate does not seem to penetrate below one foot. In the potassium sulphate plot the sub-soils contain on the average much less phosphate as would be expected owing to the growing crops making new drafts every year on their phosphate content without any return. The surface soil however contains a fair amount.

Turning now to Table I the above general deductions can be confirmed in more detail by examining the individual data of various depths. In the fallow plot the phosphate content goes down slowly up to seventh 3-inch layer, and then its concentration remains practically constant except for a slight rise in 17th and 18th layers. In the superphosphate plot the application of the phosphatic fertilizer has increased the phosphate content of the surface 9 in. of soil only, the highest being at the surface 3 in.; and below, the phosphate content decreases slowly, reaching in the 4th layer the level of the corresponding layers of the other plots. It is thus evident that the penetration of the phosphate applied at the surface soil takes place up to the surface 9 in. only. This is in agreement with the observations of Crawley [1902], Thor [1933] and other workers.

From 12 in. to 36 in. the phosphate content gradually goes down. In the next 9 in. from 36 in. to 45 in., it rises and varies inversely as the $CaCO_3$ which reaches the minimum concentration.

Except for the surface 9 in. and 12th to 15th soil layers the phosphate content of the potassium sulphate plot is generally lower than that of the corresponding soil layers of the fallow plot. The superphosphate plot too behaves in this way from 18 in. below the surface. This is demonstrated in Fig. 1 along with the inverse relationship between $CaCO_3$ and P_2O_5 contents.

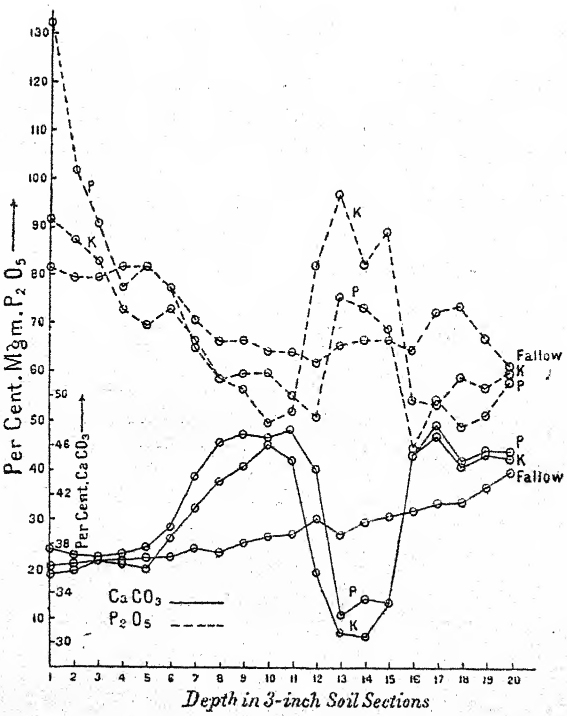

FIG. 1. The relationship between $CaCO_3$ and P_2O_5 contents of 3-inch vertical soil sections of a calcareous Pusa soil

It is conceivable that in the soil layers where the $CaCO_3$ content is high the proportion of the actual soil containing phosphate and other acidic and basic constituents and playing an active part in crop production must be less than in the soil layers where the percentage of $CaCO_3$ is comparatively low, on the assumption that the natural calcareous soil is, as it were, an admixture of soil and $CaCO_3$. As a corollary to this, the inverse relationship between $CaCO_3$ and P_2O_5 contents may take place as shown by the experimental results. This relation is not, however, regular which shows that other factors, such as, cropping and fertilizer practices, climatic conditions, or even the natural processes which took part in the formation of these calcareous soils from their parent rocks, may have influence on this relation.

Summary

As a result of phosphate fertilization, the concentration of phosphate increases only in the surface 9 in. of a calcareous soil. This indicates that phosphate remains mostly where it is placed in the soil.

Phosphate concentration in the different vertical soil layers of a calcareous soil varies inversely as the corresponding $CaCO_3$ concentration. This relation is not, however, uniform in character.

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DISTRIBUTION OF SOIL MOISTURE UNDER CROP AND ITS RELATION TO YIELD

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FOR developing sound cropping schemes, a knowledge of the water requirements of the crops and the depth from which these obtain their water supply is of great importance. Such information will be of great help in evolving judicious methods of irrigation for the tracts, where irrigation facilities are available and for selection of crops for dry-farming tracts. With this idea in view, the study was started at the Dry Farming Research Station, Rohtak. The work reported by Kanitkar [1944] from Sholapur shows that there exists a high correlation between the total yield of crops and the total available water which is equal to the available moisture present at the time of sowing and the rainfall received after sowing of the crop. More detailed work has been carried out in the United States. Cole and Mathew [1923] while determining the use of water by spring wheat in the great plains came to the conclusion that from the amount of soil moisture present in the surface layer, at the time of seeding, it is possible to forecast the yield of spring wheat. This determination helps in deciding whether the crop should be sown or omitted from the crop system. Finnell [1929] from his studies has concluded that it is not only the moisture in the surface soil which determines the yield of the crop but sub-soil moisture also is of far reaching importance. He also concluded that though from the moisture present at the time of seeding, yields of *Sorghum* could be predicted but no valuable information could be obtained with regard to wheat. As these investigations were carried out at two different localities, there is nothing strange, if the results from both the localities were not comparable. These observations however suggest that the findings from a certain locality are not of universal application and in order to find out results of practical importance for a particular locality these are to be worked out in that locality.

Experimental

Four different crops (1) *bajra* (*Pennisetum typhoideum*), (2) *guara* (*Gyamopsis psoralioides*), (3) *gram* (*Cicer-arietinum*), and (4) wheat, were included in the study and water removed by them at different stages of their growth was found out. As these crops got almost entire supply of their water from six feet column of soil, therefore moisture was estimated down to a level of six feet, before sowing and after harvesting of crops and of varying depths in between these two dates. The data reported in each case are average values of 12 to 18 individual determinations.

Bajra. Distribution of moisture under this crop was studied during the years 1937, 1939, 1940 and 1941. In the year 1937 moisture was estimated at fortnightly intervals, and in the following years, the interval was increased to one month. Results are given in Table I.

The season during which observations were made greatly differed from year to year. In the year 1939 rains were much below the normal and therefore the crop instead of depending on the rains of the season, had to draw moisture from the soil reserve. On 20-7-1939 a month after the sowing of the crop, the crop had drawn moisture from three feet column of the soil. On 18-8-1939 the crop had further removed moisture and decreased it to 6·44 per cent from 9·19 per cent on 20-7-1939 in three feet column of soil. Later on there were further losses though small in amount. The moisture in the first foot had fallen below the wilting coefficient on 18-8-1939 and later, on 13-10-1939, it had gone even below the hygroscopic coefficient. The crop during this year removed moisture from the entire six feet layer of the soil. In the year 1937 though the summer rains were about the normal and nearly double of those in 1939, the rainfall in the month of August was only 1·20 in. against a normal of 3·72 in. There was no decrease in moisture till the end of July and the crop depended

* The work was carried out at Dry Farming Research Station, Rohtak.

for the water supply on the rains of the season, but in August there was a sudden demand on moisture present in the soil which fell from 12·52 per cent on 7-8-1937 to 6-96 per cent on 18-8-1937, in three feet column of the soil. Moisture in the first foot layer on 18-8-1937 had fallen below the wilting co-efficient. There was a further decrease in the moisture in the lower layers and at the time of harvesting there was a decrease of moisture in the entire six feet column of soil.

TABLE I

Moisture as percentage on oven dry soil (Bajra)

1937

	1-7-1937	24-7-1937	7-8-1937	18-8-1937	3-9-1937	21-9-1937	15-10-1937
Rainfall in inches	..	3·98	2·37	0·24	0·96	2·69	..
Depth—							
0-6 in.	13·00	10·86	10·00	3·52	5·02	9·49	3·56
6-12 in.	12·55	12·51	11·07	5·54	3·41	10·64	5·73
2nd ft.	12·66	14·50	13·02	7·33	6·99	7·85	7·53
3rd ft.	13·91	14·93	14·02	9·01	8·35	7·80	7·61
4th ft.	14·22	..	..	..	..	..	8·14
5th ft.	14·90	..	..	..	..	..	10·80
6th ft.	15·45	..	..	..	..	..	11·84
Average	13·99	13·70	12·52	6·96	7·02	8·57	8·38
Average for 3 ft.	13·12	13·70	12·52	6·96	7·02	8·57	6·59

1939

	20-6-1939	20-7-1939	18-8-1939	14-9-1939	13-10-1939	20-10-1939
Rainfall in inches	..	1·72	0·91	0·81	..	..
Depths—						
0-6 in.	11·00	10·56	3·08	3·14	2·10	1·93
6-12 in.	11·43	10·53	4·96	4·76	3·18	4·57
2nd ft.	10·00	8·32	6·60	5·81	6·27	6·32
3rd ft.	11·30	9·02	8·71	7·47	7·73	7·94
4th ft.	12·17	..	..	..	..	8·65
5th ft.	11·68	..	..	..	..	8·57
6th ft.	10·83	..	..	..	..	8·73
Average	11·20	9·29	6·44	5·74	5·55	7·24
Average for 3 ft.	11·84	9·29	6·44	5·74	5·55	5·84

1940

	9-7-1940	13-8-1940	13-9-1940	26-9-1940	6-10-1940
Rainfall in inches	..	5·38	2·26	1·09	..
Depths—					
0-6 in.	12·50	18·00	3·49	12·80	7·24
6-12 in.	12·11	16·59	6·47	10·00	8·29
2nd ft.	11·72	16·00	9·70	9·09	9·46
3rd ft.	13·20	14·48	11·79	12·57	11·64
4th ft.	15·10	..	13·59	14·89	13·98
5th ft.	16·43	..	..	16·09	15·95
6th ft.	16·09	..	..	17·00	16·88
Average	14·14	15·93	10·01	13·51	12·61
Average for 3 ft.	12·41	15·93	8·82	11·02	9·62

TABLE I—*contd.*

Moisture as percentage on oven dry soil (Bajra)

1941

	13-7-1941	14-8-1941	29-8-1941	14-9-1941	4-10-1941	12-10-1941	13-10-1941
Rainfall in inches	..	4·32	0·62	2·60	..	..	..
Depths—							
0-6 in.	4·91	10·51	5·49	12·45	2·38	1·88	1·44
6-12 in.	6·84	10·38	8·57	11·74	5·21	4·58	2·56
2nd ft.	8·43	8·32	8·57	8·78	7·67	6·95	5·34
3rd ft.	7·76	7·86	8·31	8·46	8·55	8·71	6·99
4th ft.	9·14	9·07	..	9·92	9·58	9·68	9·88
5th ft.	10·12	..	..	10·18	10·13	10·48	9·54
6th ft.	8·74	..	..	..	..	9·31	8·43
Average	8·18	8·92	7·97	9·89	7·94	8·06	7·03
Average for 3 ft.	7·02	8·87	7·97	9·78	6·67	6·29	4·78
	Hygroscopic coefficient						
	0-6 in.	6-12 in.	2nd ft.	3rd ft.	4th ft.	5th ft.	6th ft.
	3·03	3·70	4·41	3·89	3·69	3·79	4·12
	Wiltig coefficient						
	4·46	5·45	6·52	5·58	5·26	5·40	5·86

The rains in the years 1940 and 1941 were about normal and well distributed. In these years there was a very small decrease in the soil moisture till the middle of August, but later on the demand increased and the crop got its water supply from the moisture originally present in the soil. In the year 1940 when August rains were more copious and well distributed, the crop got its water supply from the first four feet column of soil while in the year 1941 when August rains were less and had stopped by the middle of the month, the crop removed moisture from the whole six feet column of the soil.

These results indicate that during normal years, moisture under *bajra* crop remains more or less the same as is present at the time of sowing of the crop till the middle of August but afterwards when *bajra* begins to flower and seed formation starts, it draws water from the moisture conserved in the soil. The depth from which it gets its water varies with the season but generally it draws its water from the entire six feet column of the soil though about 75 per cent of the total water required by it comes from the first three to four feet layer.

Guara. Distribution of moisture under *guara* was determined in the year 1940 when it was sown in a randomized experiments with *bajra*. Therefore the results obtained from the plots under both the crops are comparable. Distribution of moisture on different dates is given in Table II.

TABLE II

Moisture as percentage on oven dry soil

	5-7-1940	15-8-1940		13-9-1940		13-10-1940		14-11-1940	
		Cropped	Fallow	Cropped	Fallow	Cropped	Fallow	Cropped	Fallow
Rainfall in inches	..	..	5·56	..	2·26	..	1·09	..	..
Depth—									
0-6 in.	10·4	16·4	19·8	3·8	7·0	3·4	6·3	3·0	6·9
6-12 in.	8·0	15·7	16·9	5 6	13·4	6·0	12·1	5·4	11·2
2nd ft.	9·7	15·4	16·1	8·1	14·8	7·5	14·6	7·1	14·4
3rd ft.	10·1	11·5	16·5	9·0	16·9	9·8	15·4	8·1	15·4
4th ft.	10·4	..	..	10·6	18·6	10·3	15·0	10·2	..
5th ft.	11·2	..	..	..	..	11·8	16·2	11·1	..
6th ft.	11·9	..	..	..	..	..	..	12·6	..
Average	10·4	14·34	16·98	8·08	15·13	8·68	14·08	8·88	..
Average for 3 ft.	9·67	14·34	16·98	7·27	13·97	7·34	13·07	6·47	12·97

From 5-7-1940, the date on which crop was sown till 15-8-1940 there was no loss of moisture from the soil but there was increase of 4·67 per cent of moisture in three feet column of soil due to 5·56 in. of rain received during the interval. From 15-8-1940 to 13-9-1940, there was a loss of 7·07 per cent of moisture from cropped plots in a three feet layer. From 13-9-1940 to 13-10-1940, there was no apparent loss from the cropped plots while from the fallow plots, there was a loss of 0·97 per cent. From 13-10-1940 to 14-11-1940, there was a loss of 0·97 per cent moisture from the cropped plots, while from the fallow plots there was only a loss of 0·1 per cent. From the fallow plots losses occurred only from the first foot while from the cropped plots there was loss of moisture from each layer down to four feet.

When distribution of moisture under both the crops is compared, it is observed that in earlier periods more moisture was removed by *bajra* than *guara*. The total moisture removed by *bajra* was slightly more than that by *guara*. *Guara* removed comparatively more moisture from the lower layers and it was between 13-10-1940 and 14-11-1940 that it tapped moisture from the third foot, a period during which it was forming seed.

Gram. Distribution of moisture under this crop was studied during the years 1936-1937, 1940-1941 and 1941-1942. The results are given in Table III.

TABLE III

Moisture as percentage on oven dry soil (Gram)

	27-9-1936	17-10-1936	30-10-1936	20-11-1936	7-12-1936	26-12-1936	11-1-1937	27-1-1937	27-2-1937	15-3-1937	27-3-1937
					Cropped plots						
Rainfall in inches	..	..	..	..	0·34	0·52	..	..	4·31	..	0·20
Depth—											
0-6 in.	10·17	6·97	7·91	6·24	7·27	7·80	5·54	4·87	11·13	8·06	6·71
6-12 in.	13·55	8·76	10·91	8·55	9·02	10·32	8·31	7·53	14·04	12·51	12·17
2nd ft.	15·60	13·86	14·09	12·40	12·60	13·00	11·52	11·78	14·91	14·02	15·77
3rd ft.	16·21	15·42	14·99	14·45	14·02	14·23	13·14	13·45	14·77	14·22	14·88
4th ft.	15·06	..	..	..	..	..	..	..	..	..	14·91
5th ft.	15·60	..	..	..	..	..	..	..	..	..	15·51
6th ft.	16·42	..	..	..	..	..	..	..	..	..	16·13
Average	15·13	12·38	12·83	11·42	11·56	12·09	10·55	10·48	14·09	12·84	13·34
Average for 3 ft.	12·38	12·83	12·83	11·42	11·56	12·09	10·55	10·48	14·09	12·84	13·33

	29-10-1940	27-11-1940	27-12-1940	27-1-1941	3-3-1941	31-3-1941
			Cropped plots.			
Rainfall in inches	..	..	..	2·42	0·89	0·15
Depth—						
0-6 in.	5·05	3·73	4·16	11·77	5·27	2·05
6-12 in.	9·23	6·95	6·79	12·88	8·26	5·88
2nd ft.	11·75	10·22	10·78	11·86	10·32	8·11
3rd ft.	12·45	11·83	12·46	11·68	11·68	10·67
4th ft.	13·92	..	..	..	12·99	12·53
5th ft.	14·88	..	..	..	13·15	14·18
6th ft.	15·79	..	..	..	..	15·17
Average	12·65	9·13	9·57	11·95	10·98	10·77
Average for 3 ft.	10·45	9·13	9·57	11·95	9·58	7·58
			Fallow plots			
Rainfall in inches						
Depth—						
0-6 in.	6·53	4·95	4·38	13·93	8·61	6·03
6-12 in.	11·61	10·59	9·05	14·47	12·83	11·00
2nd ft.	14·52	13·38	14·37	14·66	14·14	13·52
3rd ft.	15·65	16·26	15·87	16·90	15·51	16·80
4th ft.	15 61	..	..	..	17·97	16·67
5th ft.	16·12	..	..	..	20·79	17·24
6th ft.	..	..	..	..	..	..
Average	13·97	12·44	11·98	15·25	13·46	12·95
Average for 3 ft.	13·08	12·44	11·98	15·25	15·83	15·41

TABLE III—*contd.*

Moisture as percentage on oven dry soil (Gram)—contd.

	18-10-1941	19-11-1941	16-12-1941	19-12-1941	9-1-1942	26-1-1942	24-2-1942	14-3-1942	25-3-1942
					Cropped plots				
Rainfall in inches	..	..	..	0·21	..	1·01	1·68	..	..
Depth—									
0-6 in.	4·38	4·31	3·90	3·89	3·51	6·91	9·63	4·11	2·38
6-12 in.	8·70	7·56	7·18	6·06	7·83	8·92	10·41	7·76	5·57
2nd ft.	12·02	10·49	10·01	10·88	11·11	9·49	9·80	9·02	8·55
3rd ft.	11·06	10·33	9·83	10·97	11·04	10·06	10·15	10·23	10·44
4th ft.	11·42	..	..	11·87	12·04	11·50	11·83	11·22	11·88
5th ft.	12·90	..	..	..	13·41	12·32	13·04	12·48	12·55
6th ft.	12·02	..	..	..	10·54	11·84	11·26	11·27	11·40
Average	10·99	8·92	8·47	9·68	10·64	10·52	11·02	10·03	9·80
Average for 3 ft.	9·87	8·92	8·47	8·91	9·27	9·16	9·99	8·40	7·66
					Fallow plots				
Rainfall in inches									
Depth—									
0-6 in.	5·15	3·98	3·08	3·90	3·28	7·22	13·67	7·30	4·50
6-12 in.	7·84	8·23	7·96	6·94	8·31	8·45	12·91	10·93	8·18
2nd ft.	12·06	12·10	12·37	11·15	12·16	10·89	11·41	12·14	11·60
3rd ft.	11·67	12·66	12·42	11·11	12·74	11·91	12·89	12·07	12·41
4th ft.	10·87	..	..	10·59	11·37	12·20	12·54	11·49	12·53
5th ft.	9·20	..	..	..	10·69	10·89	10·21	10·71	10·71
6th ft.	8·98	..	..	..	8·27	8·39	10·01	8·45	9·39
Average	9·88	10·29	10·10	9·59	10·17	10·69	11·64	10·67	10·50
Average for 3 ft.	10·08	10·29	10·10	9·23	10·23	10·21	12·35	11·11	10·12

The results obtained 20 to 30 days after the sowing of the crop show, that there was fall in moisture in the whole three feet column of soil, the fall being more in the surface foot than in the lower layers. Later on losses were very small and gradual, the losses being more from the lower layers than from the surface foot. About the middle of January, demand of the crop for water increased and it removed moisture from the second and the third foot. From about the end of January till the end of February or beginning of March the losses of moisture from the soil were small and gradual. Later on demand of the crop for water greatly increased and there was a big fall in the entire six feet column of soil; the decrease being more in the upper three feet layer than in the lower three feet.

Moisture in the first six inches was reduced below the hygroscopic coefficient while in the second six inches, it was about the wilting coefficient and in the fallow plots moisture was always higher than the cropped plots and it was generally above the wilting coefficient. Increase in moisture due to rains was more in the fallow plots than in the cropped ones.

Wheat.—Movement of moisture under this crop was studied during 1936-1937 and 1938-1939. The results are given in Table IV.

TABLE IV

Moisture as percentage on oven dry soil

1937

	30-10-1936	12-11-1936	27-11-1936	12-12-1936	12-1-1937	19-2-1937	5-3-1937	19-3-1937	3-4-1937	20-4-1937
Rainfall in inches	..	..	0·34	0·52	4·22	..	..	..	..	..
Depth—										
0-6 in.	6·52	3·98	4·46	4·77	4·05	12·68	4·67	3·47	4·32	2·33
6-12 in.	9·50	6·21	5·74	7·10	6·24	11·19	8·16	5·89	5·71	4·57
2nd ft.	11·81	9·83	8·05	9·92	9·67	12·93	10·66	7·85	7·49	5·18
3rd ft.	12·19	11·86	10·33	11·21	11·22	11·00	11·50	9·76	8·47	6·04
4th ft.	11·91	10·80	..	..	11·28	10·33	9·89	9·60	9·67	7·99
5th ft.	10·70	9·74	..	..	9·76	10·28	12·20	9·34	..	9·71
6th ft.	10·16	9·25	..	..	9·82	9·07	9·20	10·33	..	9·72
Average	10·80	9·43	7·83	9·02	9·48	10·93	9·97	8·59	7·66	7·01
Average for 3 ft.	10·67	8·93	7·83	9·02	8·68	11·96	9·52	7·43	6·99	4·89

1938

	17-11-1938	18-11-1938	10-12-1938	10-1-1938	18-2-1938	19-2-1938	17-4-1938
Rainfall in inches	..	..	..	..	0·40	2·46	0·55
Depth—							
0-6 in.	13·34	11·69	8·55	5·39	7·03	6·34	4·09
6-12 in.	15·00	14·04	11·88	7·47	9·52	8·58	6·51
2nd ft.	16·93	13·83	13·35	10·65	10·02	9·77	9·20
3rd ft.	16·18	..	12·85	11·69	11·66	11·04	10·83
4th ft.	14·72	..	..	..	11·23	9·65	10·14
5th ft.	13·63	..	..	..	11·79	11·82	12·86
6th ft.	13·37	..	..	..	..	11·82	13·63
Average	14·83	13·35	12·13	9·59	10·59	10·26	10·31
Average for 3 ft.	15·76	13·35	12·13	9·59	9·98	9·42	8·44

Distribution of moisture under wheat is more or less similar to that under gram. First sampling after sowing was done after 12 days when germination was almost complete. The results show that there was considerable fall in moisture during this period. There was fall of moisture in the entire six feet column of the soil, though considerable loss occurred from the first two feet. Later on fall in moisture was gradual and small from the first three feet layers till the beginning of March when losses became large. This period coincides with flowering and seed formation in wheat. During this period also, considerable losses only occur from the first three feet; the losses from the lower layers are small; and insignificant.

In the year 1938-1939 there were no rains and the fields were irrigated for sowing of the crop. Therefore there was a higher status of moisture in these fields than is generally found under dry farming. As the moisture in the year 1938-1939 was at a higher level than in the year 1936-1937, there were losses in the year 1938-1939, especially from the first two feet layer.

DISCUSSION

Distribution of moisture and the yield of the crop

Kharif *crops.* *Kharif* crops put on more of vegetative growth than *rabi* crops (Tables V and VI) and therefore to sustain these more water is required. In case of drought, it is the *kharif* crops which suffer more. Out of the two *kharif* crops *bajra* and *guara*, it is the former which suffers more, on

account of its larger vegetative growth. In order to maintain its heavy vegetative growth, *bajra* taps the lower layers for water even in the early stages of its growth (Table I). During August when the crop starts seed formation, its need for water increases and water in the soil is not enough to meet its requirements. If in August rains fail, *bajra* crop begins to dry up and the grain yield becomes very poor. On the other hand, *guara* does not put on large vegetative growth and to maintain this amount of vegetative growth, it generally depends on the moisture in the upper layers and when extra water is required for seed formation, it taps the lower layers and thus forms the seeds. *Guara* therefore forms seeds even in conditions in which rains are low and which *bajra* fails to form grain. The above conclusions have the support of the yield data. Yield of both the crops along with the moisture data are given in Table V.

TABLE V

Yield of crops and the moisture data

	1936	1937	1938	1939	1940	1941	1942
Bajra.							
Moisture in three feet column of soil before sowing							
	9·74	10·88	6·23	8·17	9·99	7·96	9·43
Yield in pounds per acre							
Grain	1017	512	*Nil*	135	828	512	968
Straw	3194	2768	123	1947	3030	1515	2975
Guara							
Moisture in three feet column of soil before sowing							
	11·91	9·92	6·69	6·64	8·36	7·30	9·33
Yield in pounds per acre.							
Grain	1298	981	220	553	648	619	1366
Straw	3588	..	..	..	..	950	..
Rainfall in inches in August	6·31	1·20	1·68	1·01	6·46	4·34	7·16
Total summer rainfall	17·55	12·92	6·73	7·40	10·91	13·17	25·47

From the above results it is observed that *guara* has been giving more yield of grain than *bajra* except in the year 1940. In 1940 though the total rain-fall was slightly less than the normal, August rains were double the normal and therefore *bajra* gave higher yields. Yields of straw for *guara* are available only for the year 1936 and 1941. In the year 1936, the rains were above normal and well distributed while in the year 1941 rains were about normal and were not so well distributed as in the year 1936. In the year 1936, grain to straw ratio in the case of *guara* was larger while in the year 1941 it was smaller. In the case of *bajra* reverse is the case. In the years 1936, 1941 and 1942, when the rains were normal or rather above the normal, the grain to straw ratio was narrow, while in the years 1937, 1938 and 1939, when August rains were defective, the grain to straw ratio was larger and the yield of grain poor. These results are in accordance with the distribution of moisture already discussed. *Bajra* puts on a large amount of vegetative growth and to maintain it, it has to tap the lower layers and therefore in the month of August when grain formation starts, *bajra* badly stands in need of water. On the other hand, *guara* in the years of low rainfall or when there is low moisture in the soil, decreases its vegetative growth to such an extent that it can be maintained with the water stored in the upper two feet layer and, at the time of seed formation, it draws more water from the lower layers and therefore its yield is more than that of *bajra*.

Correlations have been worked out between the moisture present before sowing, rainfall in August, total rainfall and the yield of the crops. The correlation is not significant between the yield of *bajra* grain and moisture at the time of sowing but it is significant between the yield and the rains in August (0·8852) or the total rainfall (0·8120). On the other hand, correlation between the yield of straw and moisture present at the time of sowing is significant (0·7363), while the other two correlations are not significant. These results indicate that moisture at the time of sowing influences the yield of straw and not that of grain.

Correlations of these factors with regard to the yield of *guara* grain show that there is a significant effect of moisture at the time of sowing (0·8505) and the total rainfall (0·9072) on the yield, but there exists no such correlation between the rains in August and the yield.

These calculations support the observations already made that for obtaining normal yield of *bajra* grain, August rains are very essential but these are immaterial for *guara*.

Rabi *crops*. The yield of both the crops along with moisture present at the time of sowing and winter rainfall are given in Table VI.

TABLE VI

Yield of gram and wheat, moisture at the time of sowing and winter rainfall

	1936-1937	1937-1938	1939-1940	1940-1941	1941-1942	1942-1943
Gram						
Moisture in three feet column of soil before sowing	14·01	12·50	8·51	12·00	9·85	14·12
Yield in lb. per acre						
Grain	1588	788	89	837	395	1562
Straw	2355	880	.	824	402	1490
Wheat						
Moisture in three feet column of soil before sowing	13·36	11·61	7·60	11·14	9·85	13·79
Yield in lb. per acre						
Grain	1497	632	390	529	246	1046
Straw	1971	1071	475	673	324	1036
Rainfall in inches December and January	0·86	1·51	..	0·98	2·42	1·22
Total winter rainfall	5·37	1·52	3·41	5·80	3·46	2·90

Gram puts on more of vegetative growth than wheat and therefore there has always been more of gram straw than wheat straw and, in order to maintain it, it draws more moisture from the soil than wheat. In the year 1939-1940 when there was low moisture in the soil and there were no early winter rains, gram crop totally failed and gave very poor yield of 89 lb. per acre but that of wheat was 390 lb. per acre. In other years when there were early winter rains, gram grain was more than wheat grain.

Correlations between the moisture present at the time of sowing and the yield of gram grain (0·9819) and gram straw (0·9006) are significant and those between moisture present and wheat grain and wheat straw are not significant. There exist no significant correlation between the rains received in December and January and the yields. In the case of total winter rains there is a high correlation between these and the yield of wheat grain (0·8810) but there is no such correlation with regard to the yield of gram crop.

These results show that gram crop for its water requirement depends mainly on the moisture conserved in the soil. When moisture in the soil is low, early showers of the winter rains in the end of December or beginning of January are essential. On the other hand, wheat does not depend so much on the moisture conserved in the soil as gram and winter rains are of great use for producing a normal wheat crop.

These results further suggest that the yield of *guara* and gram can be predicted with fair accuracy from moisture present at the time of sowing.

Summary

In the early stage of growth, *kharif* crops (*bajra* and *guara*) generally depend on the rains and moisture in the soil remains more or less the same as at the time of sowing till the middle of August. After the middle of August the crops draw moisture from the soil and more water is drawn by *bajra* than *guara*. In order to get a normal yield of *bajra* grain, rains in August are a necessity. However, *guara* at the time of seed formation obtains moisture from the deeper depths and therefore in the years of defective rainfall the yield of *guara* is more than that of *bajra*.

About 20 days after the sowing of *rabi* crops (wheat and gram) there is considerable fall in moisture, decrease being more from the first two feet than the lower layers. Later on fall in moisture is gradual and small in amount. From the end of February or the beginning of March the demand of the crop for water increases and there is considerable decrease of moisture in the entire six feet.

A high correlation exists between the moisture at the time of sowing and the yields of *guara* and gram, but no such correlation exists in the case of the yields of *bajra* and wheat. A correlation between the winter rains and the yield of *rabi* crops shows that winter rains are beneficial for the formation of wheat grain but they do not influence the yields of gram, which are mainly dependent on the moisture conserved in the soil.

A high correlation exists between the August rains and the yield of *bajra* and it shows that for a normal yield of the crop, August rains are a necessity.

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POT CULTURE EXPERIMENTS ON THE MANURIAL VALUES OF COMPOSTED AND UNCOMPOSTED MATERIALS*

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Manurial trials in field plots as well as in pot cultures, using composts prepared by different methods and uncomposted materials, were carried out in the Experimental Farm attached to the Indian Institute of Science, Bangalore, during the period 1938-1941. The main results obtained in the pot culture studies are presented in this paper.

Materials and methods

The soil used for the pot cultures was a local red-loam of physical and chemical composition as shown in Table I.

Table I

Analysis of soil used for pot cultures

Mechanical composition		Chemical composition	
Coarse sand	33·4 per cent	Total carbon	0·59 per cent
Fine sand	26·4 ,,	,, nitrogen	0·058 ,,
Silt	7·7 ,,	,, P_2O_5	0·02 ,,
Clay	26·4 ,,	,, K_2O	0·22 ,,
Moisture	3·84 ,,	,, lime (CaO)	0·10 ,,
Loss on ignition	3·19 ,,	Silica (SiO_2)	77·76 ,,
Carbonate	*nil*	Iron and alumina ($Fe_2O_3+Al_2O_3$)	13·75 ,,
*p*H	6·2 ,,		

It would be noted that the soil is poor in phosphoric acid, but contains average amounts of nitrogen and carbon for Indian red-loams.

Twenty lb. of the above soil were well mixed with 10 lb. of washed sand and added to each pot. The manure selected for trial was mixed uniformly with the surface layer of soil to a depth of five to six inches, after which water was added and the manure was allowed to decompose in the soil for a period of two to three weeks before the crop was sown. Each treatment was replicated six times and the pots were kept in six parallel blocks; and within each block the individual positions of the pots were randomized.

Two crops were tried, viz. *ragi* (*Eleucine coracana*) and *jowar* (*Andropogan sorghum*). *Ragi* was grown as the first crop and *jowar* as the second crop in the same pots—the latter in order to assess the residual values of the manures. *Ragi* was transplanted into the pots from a seed-bed when 20 days old; four seedlings of the same height and vigour were distributed to each pot and these were thinned to three plants after about 10 days. The pots were watered every day till shortly prior to harvest. The grain and plant tissues were weighed separately.

After the *ragi* was harvested, the soil in the pots was well stirred and the root system was allowed to decompose for five to six weeks, with moistening of the soil from time to time. After this period, *jowar* was grown as a fodder crop. Four seeds were sown in each pot and the seedlings were thinned down to two after a fortnight. The *jowar* was removed at the flowering stage, dried and weighed.

* Work carried out under the Scheme for the 'Preparation of compost manure from town refuse and other waste material' financed by the Imperial Council of Agricultural Research.

Series I

Comparison of different types of composts

The first series of trials was devoted to a comparison of composts prepared from different types of refuse material, viz. (a) compost prepared from mixed vegetable refuse, to which only a small quantity of cattle dung was added as starter; (b) compost prepared from town refuse and night-soil; (c) a poudrette prepared by mixing night-soil with wood-ash; (d) a sample of farmyard manure obtained locally; and (e) ammonium sulphate. Including the untreated 'control' pots, there were six treatments in all. The analyses of the different manures used, in regard to their content of carbon and nitrogen are given in Table II. The manures were applied on enquivalent nitrogen basis, at the rate of one gram of nitrogen per pot. The yields of the first crop of *ragi* (grain and straw) and the succeeding crop of *jowar* are given in Table III.

Table II

Analysis of manures used (on dry basis)

Manure	Carbon	Nitrogen	C/N ratio
	Per cent	Per cent	
I. Compost from mixed farm refuse	10·14	0·98	10·35
II. Compost from town refuse and night-soil	13·26	1·26	10·52
III. Wood-ash and night soil poudrette	11·12	1·32	8·43
IV. Farmyard manure	14·96	1·38	10·84

Table III

Comparison of different manures (mean yield per pot—dry matter)

Manure applied (one gm. nitrogen per pot)	Ragi			*Jowar* fodder (dry weight). (gm.)
	Grain (gm.)	Straw (gm.)	Total dry matter (gm.)	
A Control (unmanured)	5·42	8·25	13·67	15·43
B Farm refuse compost	8·38	12·15	20·53	24·47
C Town refuse and night-soil compost	9·62	14·78	24·40	32·70
D Night soil and wood-ash poudrette.	12·58	21·12	33·70	37·10
E Farmyard manure	9·23	15·45	24·68	28·47
F Ammonium sulphate	8·18	11·87	20·05	19·47
Critical difference ($P = 0·05$)	2·81	3·01	4·76	5·14

It would be noticed that all the manures tried (B to F) have given significantly higher yields of crop than the unmanured control soil (A). In regard to *ragi* grain, the compost prepared from mixed farm refuse (treatment B), compost prepared from town refuse and night-soil (treatment C), farmyard manure (E), and ammonium sulphate (F) have given similar increases of yield, whereas the poudrette prepared by admixture of wood-ash with night-soil (treatment D) stands out significantly superior to any of the other manures.

The increases in yields of *ragi* straw in the first season and of *jowar* in the succeeding season are also highly significant for all treatments. These stand in the ascending order of effectiveness as follows: ammonimum sulphate, compost from farm refuse, compost from town refuse and night-soil, farm-yard manure and finally poudrette from night-soil and wood-ash. All the manures, except ammonium sulphate, leave a highly significant residual effect in the soil, and the extent of the residual effect in the second season is in general proportional to the manurial efficiency of the product as shown in the first season.

A comparison of the analytical figures given in Table II with the yield data presented in Table III would show that even though all the manures have been applied on equal nitrogen basis and though the C/N ratios of the composts prepared from mixed farm refuse (treatment B) and from town refuse and night-soil (treatment C) are similar to the C/N ratio of farmyard manure (E), definite differences are observed in the manurial values of the three products. The compost prepared from town refuse and night-soil (C) is equal in efficiency to farmyard manure, whereas the compost prepared from mixed farm refuse low in dung (B) appears to be somewhat poorer in quality. This difference is possibly due to the fact that both farmyard manure and compost (C) were prepared from raw products rich in nitrogen, viz. night-soil in the one case and cattle dung and urine in the other, whereas compost (B) had been prepared from a main bulk of vegetable refuse to which only a small quantity of dung was added as starter. It would thus seem that the C/N ratio of a compost product can by itself give no reliable indication of its manurial efficiency; but it would be necessary to know also the mature and quantities of the refuse materials used in the preparation of the compost.

The outstanding superiority of manure D (wood-ash plus night-soil poudrette) is presumably due to the additional effect of the phosphoric acid (contained in wood-ash) superimposed on the beneficial effect of nitrogen contained in night-soil. The red-loam soil used in the present studies being poor in phosphoric acid, the effect of added phosphoric acid has been considerable. That the effect was not appreciably due to correction of soil acidity by lime contained in wood-ash was shown by other crop experiments (not included in the present paper) wherein lime and superphosphate were added separately to the soil under examination.

Series II

Influence of uncomposted materials on plant growth

The results obtained at Rothamsted [Annual Reports, 1935-1939] and at Tocklai [Cooper, 1939] indicate that, under favourable conditions, uncomposted refuse materials could be directly applied to land, with beneficial results on plant growth equal to, and in some cases even superior, to those obtained by application of compost manure prepared from the above refuse. At Rothamsted, straw supplemented by *adco* has been tried, while at Tocklai, mixed farm wastes supplemented by starters such as *niciphos* have been used. The C/N ratios of the uncomposted mixed refuse (along with the starter) used in the above cases were round about 30.

It is well known that green manures with C/N ratios narrower than 20 could be applied directly to land with beneficial results on crop growth. On the other hand, it is also known that materials of wide C/N ratios such as straw (C/N near 80) or sugarcane trash (C/N from 100 to 120) react adversely on subsequent crop growth by lowering the available nitrogen content of the soil. The behaviour of mixtures of different vegetable wastes possessing intermediary C/N ratios, i.e. between 20 and 80 has not however received much attention.

In view of the results obtained at Rothamsted and at Tocklai, it seemed worthwhile to examine the question over a wider range of C/N ratios. The C/N ratios tried were 100, 80, 60, 50, 40, 30 and 20 and these were secured by admixing suitable proportions of sugarcane trash, *katcha* (coarse) grass, mixed fallen leaves, weeds, hongay leaves (all dried and cut into small pieces) and cattle dung, as shown in Table IV.

The quantity of mixed refuse added per pot contained one gram of nitrogen, except in the case of C/N ratios 100 and 80 (treatments B and C in Table IV) wherein it was found possible to add only a quantity of refuse containing about 0·5 gm. of nitrogen, on account of the large bulk of the refuse which had to be added in order to supply even 0·5 gm. of nitrogen. The refuse was well mixed in each case with the top three or four inches of soil in the pot, watered and allowed to decompose in the soil for a period of two weeks, with addition of water from time to time. After this period, *ragi* was transplanted in a manner similar to that in Series I.

TABLE IV

Mixed refuse at different C/N levels

	Air dry materials.						Total C and N taken	
	Sugarcane trash	*Katcha* grass	Fallen leaves	Mixed weeds	*Hongey* leaves	Cattle dung (fresh)	Carbon	Nitrogen
Analysis (on air dry basis, except dung which is on fresh basis).	*Percentages.*							
Carbon . .	41·0	39·0	28·0	37·0	41·0	7·3	..	..
Nitrogen . .	0·42	0·50	0·99	2·20	3·10	0·30	..	..
	Weights in grams							
Quantities of constituents taken for obtaining the desired C/N ratio								
(B) C/N 100 :1 . .	125	..	..	..	..	..	51·25	0·525
(C) „ 80 :1 . .	55	40	..	..	..	20	39·5	0·48
(D) „ 60 :1 . .	75	50	12	5	5	20	59·1	1·00
(E) „ 50 :1 . .	50	50	10	10	5	20	50·0	0·99
(F) „ 40 :1 . .	50	20	10	10	10	20	40·4	1·00
(G) „ 30 :1 . .	30	10	10	10	15	20	30·3	1·00
(H) „ 20 :1 . .	..	10	10	15	15	20	19·9	0·99

After *ragi* was harvested, *jowar* was grown as a succeeding crop, in order to test the residual effect of the manures added. The crop yields obtained are given in Table V.

TABLE V

Influence on corp growth of uncomposted mixed refuse at different C/N levels

Manure applied	*Ragi* Grain (gm.)	*Ragi* Straw (gm.)	*Ragi* Total dry matter (gm.)	*Jowar* fodder (total dry matter) (gm.)
(A) Control (no manure)	6·35	9·88	16·23	20·20
(B) Mixed refuse C/N 100 :1	5·03	7·73	12·76	22·38
(C) „ 80 :1	5·58	8·37	13·95	26·87
(D) „ 60 :1	6·15	9·27	15·42	34·73
(E) „ 50 :1	6·88	10·47	17·35	40·13
(F) „ 40 :1	7·76	12·37	20·13	42·77
(G) „ 30 :1	8·92	15·43	24·35	41·37
(H) „ 20 :1	9·95	20·23	30·18	38·77
Critical difference ($P = 0·05$)	1·77	2·89	3·91	5·21

The data presented in Table V lead to the following inferences :

(1) When the over-all C/N ratio of the mixed refuse is wider than 50 : 1, there is a definite depressing effect on crop yield ; and the depressing effect is greater, the wider the C/N ratio of the mixed refuse added. The lowering of crop yield, however, is not found to be statistically significant in the present experiment. As already explained in an earlier paragraph, the quantity of refuse added at the two levels C/N 100 and 80 represented the addition of about 0·5 gm. of nitrogen only per pot, whereas double that quantity was added at other levels. It is possible that if the quantity of refuse added had been doubled at the above two levels, the lowering of crop yield might have been greater and significant (Table VI). A second factor, probably, was the addition of water at regular intervals to the pots for two weeks after application of manure, which might have promoted rapid decomposition of the refuse and narrowing of the C/N ratio before the crop was sown.

(2) When the C/N ratio of the added mixed refuse is narrower than 50, the harmful effect disappears and is replaced by a beneficial effect on crop growth, which increases with narrower C/N ratios. The beneficial effect is not significant at the C/N level of 40 (treatment F) in the matter of *ragi* grain or straw taken separately ; but becomes significant when the total dry matter produced (grain and straw) is considered. The increases produced in grain and straw become individually quite significant at C/N levels of 30 and narrower, thus confirming the beneficial results obtained at Rothamsted [Annual Reports, 1935-1939] and at Tocklai [Cooper, 1939] when uncomposted refuse was applied at the above C/N level.

(3) As regards the residual values left behind in the soil by the refuse added in the previous season, it would be noted from Table V that the depressing effect of mixed refuse of C/N ratios 100 and 80 persisted only during the first season of application. In the succeeding season, a beneficial result was obtained though not significant. The residual effect was highly significant in the case of the other treatments, especially where the initial C/N ratios of added refuse were narrower than 50 : 1.

Series III

Influence of sugarcane trash supplemented by ammonium sulphate

Series III and IV were devoted to a special consideration of the utilization of sugarcane trash (leaves and tops), of which large quantities (10 to 15 million tons per year) are available in India, but are mostly burnt away.

As the replenishment of the organic matter level of cane soils is an important factor in successful cane cultivation and as the composting of cane trash is a tedious operation extending over several months [Tambe and Wad, 1935], it was considered advisable to examine whether favourable crop yields could be obtained by directly incorporating cane trash into the soil, along with a suitable dosage of ammonium sulphate so as to narrow the C/N ratio of the material to a level, which would overcome the harmful effect produced by application of trash alone.

For this purpose, a series of pots were set up to which were added respectively : (i) no manure (Series A), (ii) 100 gm. cane trash only (series B), and (iii) mixtures of 100 gm. cane trash along with increasing dosages of nitrogen, viz. 0·25 gm.0·5 gm., 0·75 gm. 1·0 gm., 1·25 gm. and 1·5 gm. of nitrogen in the form of ammonium sulphate (series C, D, E, F, G and H). Each series carried six replicates. The C/N ratios of the mixtures added in the different cases are shown in Table VI ; these varied from 97·63 to 21·35—roughly over the same range as the uncomposted refuse mixtures tried in series II (Table V).

In order to promote uniform admixture with the soils the cane trash was cut into small pieces and mixed with the top three or four inches of soil, moistened with water and allowed to decompose for a period of 10 days. After this, the required quantity of ammonium sulphate was added in solution and distributed uniformly over the top surface, which was then stirred up and well mixed. At the end of another five days, *ragi* seedlings were transplanted into the pots. The succeeding details were the same as in the earlier series.

Since the second crop of *jowar*, grown in order to test the residual effect, was badly damaged by insects, the yield data for the first crop of *ragi* only are given in Table VI.

TABLE VI

Influence of sugarcane trash supplemented by ammonium sulphate

Manure applied	C/N ratio	Mean yield of *ragi* per pot		
		Grain (gm.)	Straw (gm.)	Total dry matter (gm.)
(A) Control (no manure)	..	5·93	11·13	17·06
(B) 100 gm. cane trash only	97·63	3·47	5·38	8·85
(C) „ 0·25 gm. N as ammonium sulphate	61·19	4·92	7·27	12·19
(D) „ 0·5 gm. N	44·57	5·73	9·45	15·18
(E) „ 0·75 gm. N	35·04	6·72	12·10	18·82
(F) „ 1·00 gm. N	28·87	7·77	15·42	23·19
(G) „ 1·25 gm. N	24·56	9·78	19·13	28·91
(H) „ 1·50 gm. N	21·35	11·13	23·20	34·33
Critical difference ($P = 0·05$)	..	1·96	2·21	3·61

A comparison of the data presented in Tables V and VI would show that they are in general similar, indicating that at corresponding C/N ratios the observed effects are alike whether the C/N ratio is secured by selective mixing of vegetable refuse of different C/N ratios or by adding artificials to vegetable refuse of wide C/N ratio.

In the present case, it was found that the marked depressing effect on crop yield produced by cane trash alone, can be overcome by the addition of 0·75 per cent of nitrogen on the weight of the trash. This would correspond to narrowing the C/N ratio of the trash to about 35 : 1.

A significant beneficial effect on crop yield is noticed when the nitrogenous supplement added is at one per cent level on the trash or higher. The above one per cent level of added nitrogen gives a C/N ratio of 28·87, which approximately agrees with the C/N ratio of 30 :1, found necessary with mixed vegetable refuse in Series II to give a significant increase of crop yield.

A comparison of the data presented in Table VI treatment F and Table III treatment F, wherein one gram of nitrogen in the form of ammonium sulphate had been added with and without sugarcane trash, would show that the yield of *ragi* grain is more or less similar in both cases, but the yield of straw and of total dry matter are markedly higher where sugarcane trash had been added along with ammonium sulphate (Table VI). The difference is presumably due to the improved physical and biological conditions created in the soil by the addition of cane trash.

SERIES IV

INFLUENCE OF CANE-TRASH SUPPLEMENTED BY OIL CAKE

It is a common practice on sugarcane farms to apply large quantities of oil-cake as manure. It was considered desirable to examine whether a considerable amount of cane trash could not be incorporated into the soil along with the cake, so as to provide bulky organic matter which would improve the physical condition of the soil and react beneficially on crop growth.

For this purpose, a series of pot cultures was run on lines quite similar to Series III, except that hongey cake (containing 4·2 per cent nitrogen and 1·95 per cent P_2O_5) was substituted in place of ammonium sulphate. There were eight treatments (Table VII) as in the last series, with graded doses of hongey-cake so as to provide nitrogenous supplements at the rate of 0·25 gm., 0·50 gm., 0·75 gm., 1·0 gm., 1·25 gm. and 1·50 gm. nitrogen per 100 gm. sugarcane trash added. The cane trash (cut into small pieces) and hongey cake were added to the pots at the same time and well mixed with the top layer of soil, moistened with water and allowed to decompose for a period of two weeks before transplanting *ragi*. Series III and IV were run simultaneously and in the latter also the second crop of *jowar* had to be discarded on account of a bad insect attack.

The yields of the first crop of *ragi* (grain and straw) are given in Table VII.

TABLE VII

Influence of mixtures of sugarcane trash and hongey cake

Manure applied	C/N ratio	Mean yield per pot of *ragi*		
		Grain (gm.)	Straw (gm.)	Total dry matter (gm.)
(A) Control (no manure)	..	5·23	10·18	15·41
(B) 100 gm. sugarcane trash only	97·63	4·03	6·40	10·43
(C) ,, plus hongey cake at 0·25 gm. N	61·19	5·10	9·37	14·47
(D) ,, at 0·50 gm. N	44·57	7·25	12·43	19·68
(E) ,, at 0·75 gm. N	35·04	9·52	16·07	25·59
(F) ,, at 1·00 gm. N	28·87	11·57	19·75	31·32
(G) ,, at 1·25 gm. N	24·56	13·52	23·13	36·65
(H) ,, at 1·50 gm. N	21·35	15·15	26·03	41·18
Critical difference ($P = 0·05$)	..	1·67	2·90	3·19

A comparison of the data presented in Tables VI and VII shows not only general similarity, but also reveals some marked differences in the magnitude of effects produced. While in the case of cane trash plus ammonium sulphate, the latter had to be added at a level 0·75 per cent nitrogen on the trash in order to overcome the depressing effect on succeeding crop growth, and at a level of 1·00 per cent nitrogen in order to obtain a significant increase in crop yield over the untreated soil, in the present series of cane trash plus hongey cake, the addition of the latter at a level of 0·5 per cent nitrogen is sufficient to give a significant increase of crop yield. The above difference in behaviour between ammonium sulphate and hongey cake is explainable as being due to the fact that hongey cake contains a good amount of phosphoric acid (1·95 per cent), which exerts a positive influence on crop yield, supplementary to the effect of nitrogen contained in it.

The influence of the phosphoric acid present in hongey cake is also noticed in the relative ratios of grain/straw in the data presented in Tables VI and VII. It would be noticed that while the ratio is near 0·5 in Table VI it is near 0·6 in Table VII. For each definite weight of straw, the corresponding weight of grain is greater in Table VII than in Table VI.

DISCUSSION

The present pot culture experiments reveal that the C/N ratio of a compost by itself cannot give a reliable indication of its manurial behaviour. Composts possessing C/N ratios near 10 : 1 may vary greatly in their effect on crop yield, depending on the nature of refuse materials that were used in their preparation. Evidently, there appears to be considerable variation in the degree of availability of nitrogen and of phosphoric acid present in composts, even though the C/N ratios may be quite similar. In an earlier paper [Acharya, Parthasarathy and Sabnis, 1945] it was suggested that the above differences in availability of nitrogen may be related to the proportion of $\frac{\text{microbial}}{\text{residual}}$ nitrogen that may be present in composts. Very little work has, however, been carried out in this direction.

The present experiments also indicate that mixed farm wastes could be applied to land directly without prior composting, provided that the C/N ratio of the mixed refuse is 30 or narrower. The advantage of the above procedure would be that the cost and trouble of preparing compost could be avoided, but on the other hand, the cost of application to land may be increased on account of the larger bulk of refuse that would have to be dealt with. In addition, there are other likely disadvantages in applying uncomposted refuse to land, such as the incorporation of a large amount of weed seeds along with the refuse, which might prove a nuisance later on, the possible development

of white-ants (termites) on a large scale in the soil, and a possible depletion of soil moisture on account of the application of large quantities uncomposted dry refuse. All these factors may have a harmful effect on this succeeding crop. Further, the land itself may not be ready to receive odd quantities of refuse that would be collected every day and all such daily collections may have to be stored in some manner till the next sowing season comes in, which would again introduce the same problem of manure preparation. In certain special cases, however, especially in areas under irrigation or heavy rainfall, it may be found feasible to add uncomposted refuse directly to the land and, in such cases, the experimental data presented in this paper would indicate the safeguards, regarding the the C/N ratio of the mixed material, that would have to be adopted.

The practice of ploughing in uncomposted refuse directly into the soil may prove specially feasible in the case of sugarcane lands, which receive heavy manuring with artificials or oilcake, and where at present most of the trash is thrown away or burnt on the ground. Usually 3 to 5 tons of trash per acre are available on such lands and these could be usefully ploughed in, along with a supplement of 30-40 lb. of nitrogen in the form of oil-cake or 40-50 lb. nitrogen in the form of ammonium sulphate, preferably supplemented by some superphosphate. It would be found advisable to plough in the trash soon after the cane season is over and apply the cake or ammonium sulphate shortly before the next crop is planted. This procedure would serve to return to the soil a large quantity of organic matter and thus help to keep the soil in good physical and biological condition.

Summary

1. Pot culture experiments, growing *ragi* and *jowar* on a red-loam soil, were carried out in order to : (a) compare the manurial value of composts prepared from farm and town wastes, against farmyard manure, ash poudrette and ammonium sulphate ; and (b) to examine the effect on crop growth of the application of uncomposted refuse material of different C/N ratios ; for this purpose : (i) mixed vegetable refuse of different C/N ratios and (ii) sugarcane trash along with graded supplements of ammonium sulphate or hongey cake were tried.

2. The manures examined were found to increase crop yield in the following descending order of effectiveness : Poudrette from night-soil and wood-ash, compost from night-soil and town refuse, farmyard manure, compost from mixed farm refuse and lastly ammonium sulphate.

3. All the manures, except ammonium sulphate, left a significant residual effect in the soil.

4. Uncomposted mixed refuse produced a depressing effect on crop growth at C/N levels wider than 50 :1 and yielded significant crop increases at C/N levels of 30 :1 and narrower.

5. The application of uncomposted sugarcane trash to the soil produced a marked decrease in crop yield. The harmful effect could be overcome by the addition of ammonium sulphate at the rate of 0·75 per cent nitrogen on the dry matter of the trash. A significant increase in crop yield over untreated soil could be obtained by increasing the supplement of ammonium sulphate to a level of one per cent nitrogen on the weight of the trash.

6. The increased crop yield obtained by the addition of cane trash along with a supplement of one per cent nitrogen as ammonium sulphate was found to be better than the yield obtained by the addition of the same quantity of ammonium sulphate alone. The difference was attributed to the beneficial effects produced in the soil by the added organic matter.

7. Hongey cake was found to be more effective than ammonium sulphate in overcoming the depressing effect of sugarcane trash on crop yield. The addition of a supplement of cake at the rate of 0·5 per cent nitrogen on the weight of trash was sufficient to give a significant crop increase over the untreated soil. This superiortiy of oil-cake is attributed to the phosphoric acid contained in it.

8. The advantages and draw-backs of applying uncomposted refuse to the soil have been discussed. It is pointed out that, in the case of sugarcane soils, it may be found advisable to plough into the soil all the cane trash left on the field, along with a suitable supplement of oil-cake or ammonium sulphate, applied either along with the trash or at a later stage prior to the sowing of the next crop. It is suggested that this procedure would help to supply a large quantity of organic matter to the soil and thus to maintain the physical and biological conditions of the soil under optimum conditions for sugarcane growth.

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SOME OBSERVATIONS ON THE RUST OF GRAM (*CICER ARIETINUM* L.)

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(With two text-figures)

GRAM rust caused by *Uromyces ciceris-arietini* (Grognon) Jacz. is prevalent in several parts of India. In northern India it is common in Bihar, the United Provinces, the Punjab and the North Western Frontier Province. In the warmer districts of the U.P. and in Bihar where the crop matures earlier, the damage caused is not very appreciable but in the cooler northern districts of the U.P., the Punjab and the N.W.F.P., the appearance of the disease often coincides with the maturation period of the pod and badly rusted plants consequently give poor yields. The disease appears to be common in the countries bordering the Mediterranean and in the Balkans.

This rust has not received attention so far at the hands of the pathologists and, excepting for a brief account by Butler [1918], there is hardly any literature on the disease. It was first collected by Grognon at Soane, on the river Loire in France, and named *Uredo ciceris-arietini* by him in 1863 but the telial stage was found by Boyer near Montpellier and named by Jacjewski in the publication by Boyer and Jacjewski [1893]. The earliest record of it for India is by Barclay [1890] who tentatively placed it in *Uromyces pisi*.

The work reported here was undertaken in 1938 with a view to study the life history of the rust and to see if there are varieties of gram that are resistant to its attack. The work had to be ended, however, a year later when the first author was transferred to Cawnpore. Some of the interesting observations made in the course of the study are placed on record in this paper.

MORPHOLOGY OF THE RUST

Uromyces ciceris-arietini is a hemiform, the pycnial and the aecial stages being unknown. The uredia are as a rule hypophyllous and scattered, minute, round, pulverulent when mature and cinnamon-coloured. The urediospores are globose to subglobose, loosely echinulate, $20 \times 28\mu$ in diameter, yellowish-brown with a rather thick epispore and four to eight germ pores. The telia resemble the uredia but are darker brown ; the teliospores are variable in shape, round, ovate or angular with a roundish, unthickened apex and brown, warty or roughened wall. They measure 18 to 30μ by 18 to 24μ and have a short, hyaline pedicel from which the teliospores get readily detached. They have a single germ pore, which fact and their somewhat deeper coloured epispore distinguish them from the urediospores.

Careful search in gram fields has not revealed any pycnial or aecial stages on the gram plants nor have any weeds been found in the vicinity, bearing pycnia or aecia, which might be considered as stages in the life history of this rust.

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Symptoms of the disease

The rust appears as a rule at the end of February when the plants are about four months old. In rare cases, it has been observed as early as the first week of February. Due to this late appearance of the rust, inoculum for experimental work does not become available early enough, unless some special device is discovered for keeping the spores of the previous season viable. The symptoms which the disease produces are very simple. There is no stunting of growth, witches' broom or hypertrophy. The leaves become crowded with small, round or oval, cinnamon-brown pustules which tend to coalesce. The petioles and the stems may also bear a few pustules, especially when the rust is very severe.

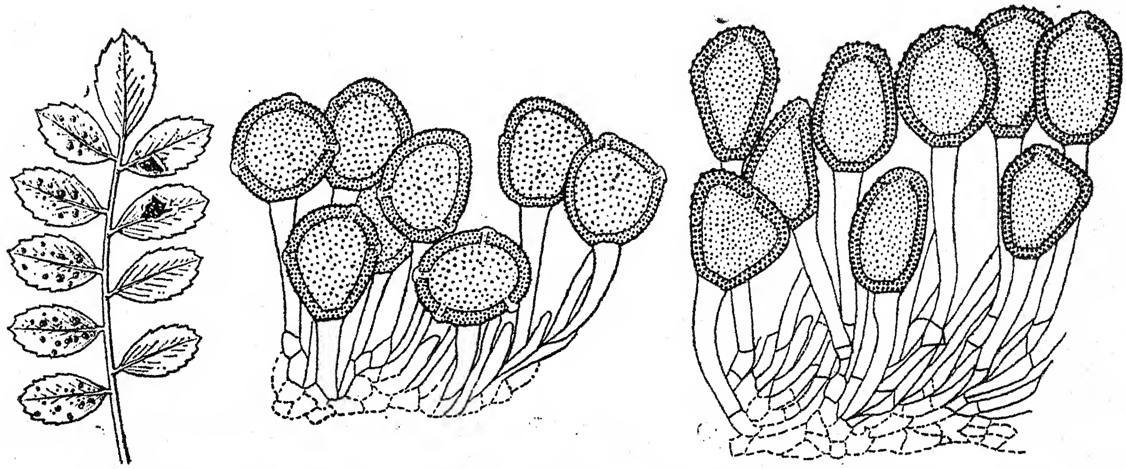

FIG. 1. Gram rust (*Uromyces ciceris-arietini*). Infected leaf × 2. Uredia and telia with spores × 750

Germination of the spores

Butler [1918] states that the urediospores remain capable of germination for at least a month but does not say whether he succeeded in germinating the teliospores. Considerable work has been done in these investigations to obtain the germination of both the spore forms and to see how long they remain viable.

Leaves of IP gram variety 17 containing both the uredia and the telia were collected in April 1938 at Karnal. The material was divided into four lots and stored under different conditions as follows :

(1) Leaves packed in cellophane packets which were then placed in stout manila envelopes and stored in a refrigerator at 6°C.

(2) Leaves placed in a dry glass tube which was then tightly corked and sealed with wax and placed in ice in the refrigerator.

(3) Leaves packed as in (1) and then buried in dry, sterilized soil in pots and these pots kept in the open.

(4) Leaves packed as in (1) and the envelopes stored in shade in the laboratory.

The urediospores and the teliospores were tested for their germination immediately before storing and the tests were repeated once a fortnight thereafter.

In order to standardize the method of germinating the spores, the following three tests were made : (1) germinating the spores in a drop of water placed on a slide and incubating them in a moist chamber ; (2) floating the spores on water in Syracuse watch glasses and then counting those that have germinated ; and (3) dusting the spores on moistened cellophane strips. The last named method gave uniformly good results and was adopted. For this purpose, the cellophane sheet was cut into strips two inches long and one inch broad and soaked in water for six hours. They were then jerked to remove excess water and placed flat on the slide. The spores were dusted on the strips with a brush and the slide then incubated in a moist chamber.

After having found the most suitable method of germinating the spores, attempts were directed towards finding a suitable medium in which to germinate them. The following liquids were tried and the results are recorded in Table I.

TABLE I

Per cent germination of urediospores at 32°C. after 36 hours

Medium	Percentage
Distilled water	88
Tap water, $pH=7{\cdot}6$	84
0·01 per cent malic acid	86
0·05 per cent malic acid	92
0·1 per cent malic acid	66

The spores germinated quite readily producing the germ tubes in two hours. The germ tubes followed a rather tortuous course, there being a single germ tube per spore in a majority of the cases. They attained a length of 200 to 400μ, after which the apical cell became markedly swollen and often lobed. The protoplasm got accumulated in the apical cell and one or two adjacent ones, while the rest of the tube was empty. As the per cent germination in distilled water was sufficiently high, it was alone used in subsequent trials.

The effect of temperature on freshly collected urediospores was then studied. The spores were mounted on cellophane strips soaked in water and the moist chambers were placed in incubators adjusted to different temperatures. The results obtained are recorded in Table II.

TABLE II

Effect of temperature on the germination of the urediospores

Temperature °C.	Per cent germination	Average length of germ tubes in μ
17	86·4	120·0
20	84·5	186·0
22	86·3	323·0
26	85·9	380·0
32	82·5	125·0
37	56·2	80·0

It will be noted from the data recorded in Table II that temperatures between 17° to 32°C. are very favourable for the germination of the spores though temperatures between 22° to 26°C. appear to favour more vigorous and better growth of the germ tubes. Above 32°C. germination declined rapidly.

VIABILITY OF THE UREDIOSPORES

Germination tests to see the viability of the urediospores stored under different conditions were conducted every fortnight commencing from 15 April, 1938. It was found that the spores from the material buried in the soil in pots and placed in the open lost their viability within two weeks. The spores from the material kept in the laboratory at room temperature of 30° to 40°C. showed only two per cent germination after two weeks and none after four weeks. The spores from the material kept in sealed glass test tubes and embedded in ice continued to germinate normally until the end of the fourteenth week when water accidentally got into the tube and the per cent germination thereafter became low and by the eighteenth week it entirely ceased. The material kept in the refrigerator chamber at 6°C. continued to germinate till the following December, that is up to 34 weeks. A gradual decline in germination became noticeable, however, after

the twentyfirst week onwards and the germ tubes showed a tendency to burst at the apex 36 hours after the spores started germination which was not shown by freshly collected spores. It will be manifest from these tests that urediospores stored under suitable conditions remain alive until long after the gram crop of the succeeding season has been sown (usually in early October). The results are shown in the following graph (Fig, 2)

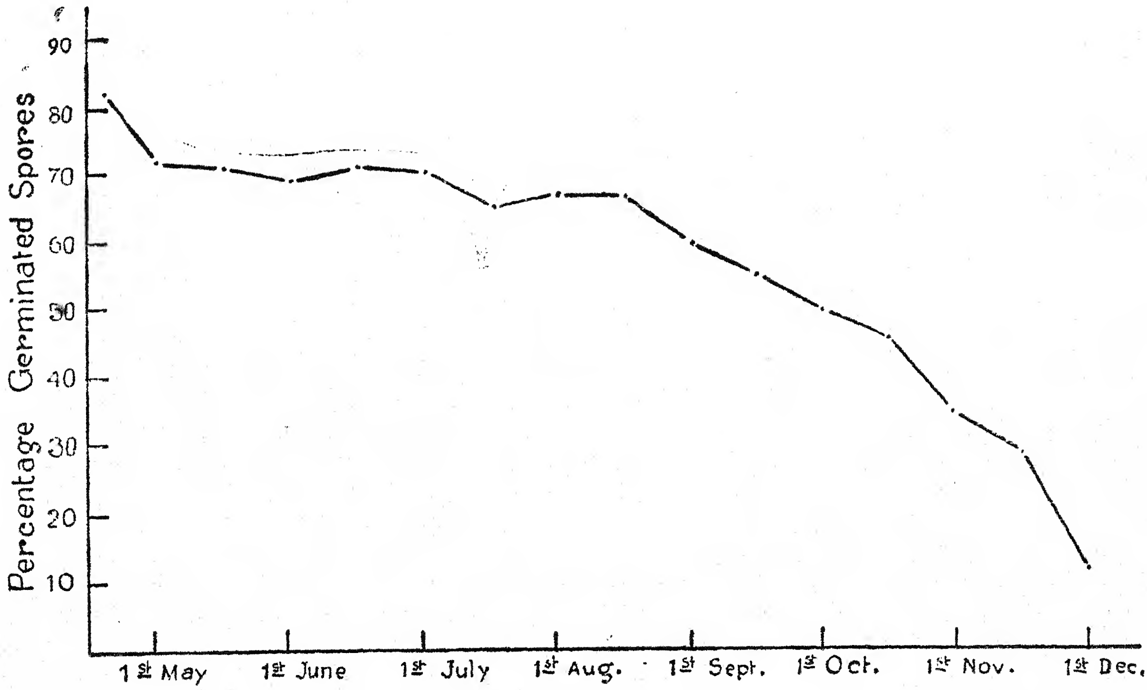

Fig. 2 Per cent germination of urediospores at different intervals of time

Germination of the teliospores

Several attempts were made to germinate the teliospores. Alternate chilling and thawing, effects of the vapours of alcohol, chloroform, different concentrations of ethylene chlorhydrin, effect of soaking the spores in water for different periods, etc. were tried. Teliospores collected early and late in the season and from sori from partially shaded plants were also given a trial. In all cases uniformly negative results were obtained. A more careful investigation is, however, necessary to elucidate the factors that induce the teliospores to germinate.

Infection experiments

Infection experiments were carried out in two ways. Clinton and McCormick [1924] reported a method of infecting detached but still living leaves of the host plant with rusts, which has been further elaborated by Waters [1928]. That method was used in the first set of experiments.

Tender shoots with a few leaves were detached from one month old plants and washed several times with sterile water. They were then placed in large petri dishes containing five per cent cane sugar solution and the urediospores were applied with a brush. These dishes were placed in incubators registering 8°C., 17°C., 20°C. and 24°C. temperatures respectively. The sugar solution was changed every third day but the shoots were exposed to strong light for half an hour daily. The results are recorded in Table III.

TABLE III

Effect of temperature on the incubation period of the uredial stage

Temperature °C.	Incubation period	Character of the sorus
8	27 days	Numerous, tiny
17	17 days	Numerous, tiny
20	13 days	Few, large
24	11 days	Few, large

The shoots kept in the incubator registering 24°C. turned yellow after two weeks. Some shoots were also kept at a temperature of 27°C. but the material could not be kept alive even for a week. Telia were not formed on any of the shoots in these experiments.

In a second set of experiments, the tests were carried out on plants growing in pots. The plants were about six weeks old. They were first sprayed with distilled water the previous evening and placed in a chamber over night. Early the next morning they were sprayed with suspensions of spores and the plants were placed in an incubation chamber for 24 hours, after which they were placed on the green house bench. Later in the evening, some pots were placed in chamber number one in the pot culture house where the temperature varied from 22°C. to 30°C., a second lot in chamber number two where the temperature varied from 20°C. to 27°C. and the last lot in chamber number three where the temperature varied from 17°C. to 24°C. The plants kept in chamber one developed chlorotic areas on the seventh day and the pustules erupted through the epidermis on the eighth day; those kept in chamber two showed the chlorotic areas on the eighth day and the sori erupted on the ninth day; those placed in chamber three showed the chlorotic areas on the eleventh day and the pustules erupted on the twelfth day.

In these experiments the urediospores used were those stored in cellophane packets and kept in the refrigerator under dry conditions at 6°C. It will be noted that the urediospores not only remain viable for over 34 weeks if stored under proper conditions but are even able to attack the host and bring about infection. The tests were carried out in November, 1938, at which time the urediospores were about 27 weeks old.

DEVELOPMENT OF THE TELIA

Plants of IP variety 17 were raised in small pots in November and the plants were infected after they were four, five, six, etc. up to sixteen weeks old using two pots for each test. The telial stage appeared towards the end of March irrespective of the time of infection or the age of the plants when they were infected. It is manifest therefore that the appearance of the telial stage depends on a complex of climatic factors that are prevalent about the end of March and not necessarily on the age of the plants when they are infected.

VARIETAL RESISTANCE

In order to determine the resistance of some gram varieties, plants were grown in small pots and infected when they were 16 days, 30 days and 45 days old. The same procedure for infecting the plants as before was followed. The pots were watered with a constant quantity of water every 36 hours. The following Imperial Pusa varieties of gram were tested: 2, 8, 9, 10, 12, 14, 17, 21, 30, 32, 43, 50, 53, 73, 78 and 82.

Due to the small size of gram leaves it was difficult to estimate the area of the leaf occupied by the sori using the method adopted by Fromme and Wingard [1921] for bean rust or the standard method in use in the United States Dept. of Agriculture for wheat rust. The following method was therefore adopted: the attacked leaves were carefully washed with water using a sprayer to remove the superficial spores which otherwise obscured the leaf area occupied by the sori. Numbers, 1, 2, 3 and 4 were then assigned to indicate the severity of infection, 1 indicating least infection and 4 the highest, for each plant as a whole.

The results thus obtained were checked by obtaining random samples of leaves, boiling them in alcohol to remove the chlorophyll so that the sori could be clearly seen and then counting the sori. In severe infections 74 sori were counted on a plant whereas in mild infection as few as eight were present. A key to the numbers to denote the severity of infection is given below :

1=Pustules very minute ; secondary sori nil ; epidermis slightly ruptured ; no chlorosis around the pustule ; leaves and rarely stipules affected.

2=Pustules medium sized ; secondary sori absent ; slight yellowing around the pustules, sometimes violet ; epidermis slightly ruptured ; leaves mainly affected, petioles only slightly.

3=Sori medium sized ; secondary sori few ; epidermis ruptured ; severe yellowing of younger leaves and production of violet colour in older ones ; leaves and petioles attacked.

4=Sori big ; secondary sori very common ; epidermis completely ruptured ; extensive chlorosis and yellowing of the leaves ; leaves, petioles and stems also attacked.

The data are presented in Table IV.

TABLE IV

Susceptibility of IP gram varieties to rust infection

Variety	Severity of infection		
	16 days old	30 days old	45 days old
2	4	4	4
8	1	3	3
9	2	2	3
10	3	4	4
12	1	4	4
14	4	3	4
17	3	3	3
21	2	3	2
30	4	4	3
32	3	2	2
43	1	3	3
50	3	2	2
52	1	2	2
53	4	3	4
63	2	3	3
78	1	2	2
82	3	1	2

From the data recorded in Table IV, it will be observed that some of the varieties do have a certain amount of seedling resistance which, however, gets broken in the adult stage. In one case, that of IP variety 82, the plants that were susceptible in the seedling stage, have shown some adult resistance. A certain amount of correlation between the age of the plants and their susceptibility to infection is indicated.

These experiments have shown that the method of infection and of taking the readings are satisfactory. The results are an indication of what can be achieved if large scale experiments are undertaken and that among the numerous varieties of gram there may be varieties that have resistance to attack by this rust, and that such investigations if undertaken may give fruitful results.

FIELD OBSERVATIONS

In April 1939, one of us (P.R.M.) proceeded to Karnal to take observations on the gram crop growing there and the extent of attack of the different varieties, of which sixty were under cultivation. The following observations were made :

Highly infected : IP 15, 22, 23, 24, 34 and 58

Moderately infected : IP 1, 2, 3, 4, 12, 14, 16, 25, 26, 28, 44 and 48

Slightly infected : IP 29, 30, 31, 32, 33, 35 and 55
No rust on plants : IP 6, 10, 11, 13, 17, 18, 19, 20, 27, 36, 37, 38, 39, 40, 41, 42, 43, 45, 46, 47, 49, 51 52, 53, 54, 56, 57, 59 and 60

Discussion

The investigations reported in this paper have furnished one definite conclusion that it is possible to keep the urediospores viable for 34 weeks, and perhaps more, so that inoculum is available for experimental work in the succeeding season without having to wait for the appearance of the disease in nature. While resistance tests have not given conclusive results, indications are that there exist varieties of gram that are resistant to this rust. In these tests it was noted that not all the plants of a single variety showed the same intensity of attack indicating that so far as their reaction to the disease is concerned, they may be heterozygous. It should be possible to build up resistance in selections from such varieties. By including a larger number of varieties obtained from all over the country and abroad and concentrating attention on adult resistance, as the disease does not appear in the fields before the plants are 10 to 12 weeks old, it should be possible, we think, to obtain highly resistant varieties.

Success has not attended our efforts to germinate the teliospores and the matter may not be simple. Further work is necessary so that the capacity of the sporidia to infect gram plants or others has to be carefully explored. As the urediospores stored at laboratory temperatures or buried in the soil lose their viability within a month, there is little doubt that in nature they do not play any role in bringing about rust epidemics. As the disease does not appear before February, and answer to the question 'where it comes from' will give clues for devising other methods for its control.

Summary

The morphology of gram rust is given and the symptoms it produces are described. It has been shown that the urediospores germinate very well in 0·05 per cent malic acid solution and also in distilled water and that a temperature of 20°C. to 26°C. favoured both good germination and the best growth of the germ tubes. Urediospores stored at room temperature or buried it in the soil in pots left in the open lost their viability in two to four weeks but if stored at a cooler temperature, especially at 6°C., they kept viable for a long time.

Detached gram leaves floated on sugar solutions were readily rusted by the urediospores of the previous season stored at 6°C. and they were also able to infect gram plants growing in pots. The incubation period for the appearance of uredia was about 27 days at 8°C. but only 11 to 13 days at 20°C. to 24°C.

A number of gram varieties were tested to see their ability to resist the disease. Some showed seedling resistance which broke down as the plants grew older. One variety which was rather susceptible in the seedling stage was mildly attacked in a more adult stage, perhaps because it had adult resistance.

Teliospores could not be germinated and the pycnial and the aecial stages are still unknown. The implications of the observations made in these investigations are discussed.

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SEED TRANSMISSION OF STEM-ROT OF JUTE AND ITS CONTROL

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(With Plate XIX and one text-figure)

Varada Rajan and Patel [1943] have suggested that the infected jute seed is a more important source of primary infection of *Macrophomina phaseoli* (Maubl) Ashby than the soil. In some samples they found as much as 30 per cent infected seeds. The work reported herein furnishes evidence for transmission of the disease through the seed, measures for the elimination of seed-borne infection and some data on the role of seed and soil-borne infections.

Seed infection

Evidence for seed-borne infection. That the disease is transmitted through the seed was suspected when superficially sterilized seeds grown asceptically in tubes produced rots, hyphal growths, and lesions on unviable seeds, sprouted seeds and seedlings. The fungus isolated from these infections was *Macrophomina phaseoli.* When the seeds were washed in sterilized water and sown on sterilized soil, 25 per cent of the seedlings were found to be infected and the symptoms were typical of the disease as it occurs in the field. When the sterilized water in which the seeds were shaken was examined under the microscope small sclerotia were noticed. This suggested that the fungus is borne on the surface of the seed. Sclerotia and pycnidia are found on the outer surface of the entire seeds.

To ascertain whether the fungus harbours within the seed, seeds were superficially sterilized and plated on potato dextrose agar and incubated at 32°C. From data given in Table I it appears that the fungus is embedded within the seed. The difference in the percentages of infection may be due to the differences in the penetrating power of the chemicals.

Table I

Test for the seed-carriage of the fungus

Treatment for 20 minutes in	No. of seeds plated	Percentage infected
Formalin 1 per cent	1586	2·67
Mercuric chloride 0·01 per cent	1651	8·11
Sulphuric acid 5 per cent	1751	4·05
Hot-water (75°C.—80°C.)	1730	0·00
Untreated	1770	8·87

Macerated seeds when examined under a binocular microscope show sclerotia and mature hyphae under the seed coat, and sometimes in the cotyledon. Hand sections of discoloured seeds show numerous sclerotia and mature hyphae within the tissues (Plate XIX, figs. 1-3)

Mode of seed-infection. Repeated observations carried out over a number of seasons have shown that the various stages by which infection takes place are as follows.

The flower-bearing branches are commonly infected through the leaves of axillary branches. The rot spreads upwards and infects the capsules. Direct infection of the capsule through pycnospores

has also been noticed. The infection covers the capsule and enters within from the apex. The sclerotia occur on the placenta as well as in the locules, but they are denser at the distal end. At the proximal end the seeds remain free from infection. The fungus penetrates the seed tissues, possibly through the micropylar end.

Mature capsules on infection often split and shed the seeds. The immature capsules on infection dry up and drop off. In split capsules, exposed seeds have pycnidia. The extent of capsule infection varies from year to year depending upon the rains. Late rains cause extensive capsule infection. Early maturing types are usually caught in the rains and are badly infected. *C. capsularis* is infected more than *C. olitorius* or other wild species of *Corchorus*.

Technique for the detection of diseased seed. Several methods were tried out for estimating the percentage of infected seed, but that of plating 30 seeds on 10 c.c. of potato dextrose agar in petri dishes (100 mm. × 15 mm.) proved the handiest and the quickest. Plated seeds were incubated at 32°C. until the germination was complete and the colonies had grown to about one centimetre. Hyphal growths were visible on the seed within 24 hours and the sclerotia could be seen in the medium within three days. By this time distinct colonies were formed around contaminated seeds. In a plate all the infected seeds did not put forth fungal growths on the same day. This variation was attributed to the differences in the extent of infection and the depth at which the fungus was embedded. While only *Macrophomina phaseoli* was commonly obtained from such isolations, occasionally *Diplodia* sp., *Phomopsis* sp., *Fusarium* sp. and some general fungal and bacterial contaminants were isolated. The stem-rot fungus could be recognized by its characteristic upright hyphal growths from the seed and by the formation of small sclerotia. The disease percentage was calculated on the number of seeds sprouted or unsprouted which yielded *Macrophomina* fungus. It only took about a week to complete the pathological examination of a sample of seed.

In determining the percentage of total infected seeds it was necessary that the fungus on the surface of the seed was not destroyed. At the same time it was essential that all bacterial contamination was eliminated. Therefore, prior to plating, the seed was dipped in one per cent sterilized lactic acid.

On the other hand, when only the percentage of seeds with deep seated infection was to be estimated it was necessary to sterilize the surface of the seed. For this purpose 0·1 per cent mercuric chloride in 70 per cent alcohol was found suitable. The seeds could be steeped up to 20 minutes without any loss in viability. Alcohol assisted in eliminating air bubbles and in preventing lump formation. If necessary, seeds were kept under partial vacuum by working the suction pump. Before plating the seeds were washed in several changes of sterile water. For obtaining reliable and reproducible results, it was necessary to sample the seeds properly. A handful of seeds might be sub-divided uniformly till approximately 30 seeds were obtained. To determine whether the sampling method was reliable, from a common bulk, five lots of samples were drawn and replicated ten times. The differences in the disease percentages between the five lots did not prove significant. This standard technique was adopted for all the experiments.

It would have been ideal if in all the experiments only seeds from a common bulk were used. But as the magnitude of the work could not be foreseen, different bulks had to be used. In the experiments that are to follow wherever the change of seeds has occurred, it has been mentioned. In all the experiments seeds of *capsularis* strain D 154 were used.

Effect of seed-borne infection on germination. Healthy seeds appear smooth, glossy and brown in colour whereas the infected seeds have a dull surface, and are often a shrunken appearance.

A sample of seed was examined under a binocular microscope, and the seeds were classified into four groups, viz. (i) with sclerotia, (ii) with hyphal growths only, (iii) light and shrivelled, and (iv) healthy. They were plated on potato dextrose agar media and percentages of germination and disease were recorded. From the data given in Table II, it may be noted that of those that were classed as healthy, 5 per cent showed the disease. Nearly 8 per cent of seeds were light and shrivelled and of these only 25 per cent germinated. Those that had sclerotia or hyphal growths either did not germinate or produced only diseased seedlings.

TABLE II

Seed analysis

—	With sclerotia	With hyphal growths	Light and shrivelled	Healthy
Number	27	11	168	1934
Percentage	1·25	0·52	7·9	90·33
Germination percentage	0·0	16·0	25·0	93·7
Per cent of diseased seedling	0·0	100·0	12·1	5·5

From numerous experiments with plated seeds it is observed that healthy seeds record a higher germination than the diseased ones. Quite healthy seeds give 90 to 95 per cent germination. In ordinary samples more than 80 per cent of seeds are viable, but in severely infected samples the germination is very poor, 40 per cent of the seeds losing their viability owing to fungal attack, and 40 per cent showing disease on germination.

Badly infected seeds do not germinate and they are the first to put forth fungal growth. Slightly infected seeds give out only a few hypae at a later stage.

The fungus may come out from any part of the seed or the seedling. Simultaneously with sprouting, the fungus growths appear at the funicular end. Primary growths may also occur independently on the cotyledons, hypocotyl, collar and radicle. Under laboratory tests the primary infection invades the entire seedling which rots and produces pycnidia and sclerotia. Under green house and field conditions, the lesions in surviving seedlings often become localized and the seedling remains stunted.

ELIMINATION OF SEED-BORNE INFECTION

Gravitational methods. As diseased seeds are lighter than healthy ones, experiments were carried out, to investigate the possibility of separating the lighter diseased seeds by flotation with a liquid of such density that all diseased seeds would float while the healthy ones remained at the bottom. By adding suitable quantity of methylated spirit (0·8) to carbon tetrachloride (1·58) its specific gravity was reduced to 1·23, 1·13 and 1·09. The results are given in Table III, from which it is evident that the gravitational methods do not hold out any promise. Even when the specific gravity was as high as 1·23, more than 10 per cent of those which sank were diseased while over 36 per cent of the float ones were healthy.

TABLE III

Seed separation by gravitational method

Specific gravity	Mean percentage of		Mean per cent germination in		Mean per cent disease in	
	Floaters	Sinkers	Floaters	Sinkers	Floaters	Sinkers
1 (H_2O)	6·2	93·8	0·0	95·8	100·0	17·0
1·09	10·1	89·9	82·8	95·0	46·1	12·2
1·13	14·6	85·4	44·1	95·0	47·2	10·2
1·23	38·4	61·6	31·8	95·5	63·5	10·4

Heat. When seeds were heated in air they lost their viability considerably without lessening the seed infection. Even between 60°C. to 62°C., about 7 per cent of seeds showed the causal fungus. Hot water treatment of seed was, therefore, thought of. Seeds were soaked in water and air within

them was evacuated by using a suction pump, or by adding a few drops of 10 per cent castile soap both of which facilitated the sinking of seeds. After heating the tube containing the seeds, in a water-bath, it was transferred to cold water. To eliminate bacterial contamination the seeds were dipped in 1 per cent sterilized lactic acid prior to plating.

The results of four exploratory experiments (where the air was evacuated by means of a pump) are given in Table IV. Taking 80 per cent germination as satisfactory, it was found that treatments at 58°C. for 7 minutes, at 57°C. for 10 minutes, or at 56°C. for 20 minutes reduce seed infection from 22 to 1 per cent.

TABLE IV

Hot water treatment of seeds (air evacuated with a pump)

Range 0°C.	Duration in minutes	Experiment I		Experiment II		Experiment III		Experiment IV	
		G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.
55	10	86·4	5·5	..	..	..	..	..	..
55	20	89·6	4·3	89·7	3·6	..	..	..	..
55	25	..	..	81·2	1·9	91·3	1·9	..	..
55	30	91·0	3·2	65·6	0·7	87·8	1·9	..	..
55	40	78·9	1·4	..	..	68·5	0·4	..	..
56	10	88·8	3·7	92·2	6·2	..	..	75·9	1·5
56	15	..	..	83·0	2·4	..	..	76·9	1·1
56	17	..	..	..	..	84·3	4·9	79·2	0·0
56	20	84·1	3·5	79·1	1·1	..	..	80·5	0·0
56	30	69·8	1·0	..	..	..	..	..	..
56	40	46·4	0·0	..	..	..	..	..	..
57	10	93·8	4·3	81·0	2·1	83·4	4·9	89·1	0·7
57	15	..	..	84·6	1·1	..	..	78·4	0·4
57	17	..	..	..	..	..	..	78·1	1·1
57	20	83·4	1·4	63·7	0·3	..	..	65·9	0·4
57	30	63·5	0·4	..	..	..	..	..	..
57	40	28·2	..	..	..	..	..	..	..
58	5	..	..	87·0	4·0	..	..	..	..
58	7	..	..	..	..	82·1	3·7	80·8	1·1
58	10	..	..	54·6	0·0	..	..	..	..
Control . . .	..	89·4	23·7	91·5	22·9	95·1	25·1	94·6	22·7
Critical difference	..	12·3	3·2	10·7	3·8	11·2	4·3	9·4	2·6

G. P.=Germination percentage; D. P.=Disease percentage

In the second set of four experiments where castile soap was used, treatments at 57°C. for 25 minutes, at 58°C. and 59°C. for 15 minutes were quite effective in reducing the disease without affecting the germination (Table V).

TABLE V

Hot water treatment (Evacuation with castile soap solution)

Duration in minutes	10		15		20		25	
Range 0°C.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.
57	93·8	7·8	81·7	8·1	76·1	10·8	84·9	2·9
58	88·3	6·1	81·2	4·5	59·6	5·3	49·9	3·9
59	82·4	6·9	87·3	4·1	46·5	3·4	68·0	2·7
60	78·2	9·4	64·8	2·6	64·7	2·4	35·5	0·0
Untreated	92·5	22·1	96·0	25·0	93·2	18·0	95·0	20·5
Critical difference . .	9·3	4·8	14·5	5·3	24·5	6·2	16·7	5·8

G. P.=Germination percentage; D. P.=Disease percentage

Since the sclerotia are associated with the mature hyphae in the seed, it was thought that pre-soaking might activate the hibernating fungus and the following hot-water treatment may prove more effective. The seeds were soaked in water from one to four hours at room temperature which averaged at 28°C. during the course of the experiment. The pre-soaked seeds were subjected for 15 minutes to treatments from 48°C. to 62°C. at one degree intervals, and after cooling were plated. From 48°C. to 55°C. the same sample of seed was used, but from 56°C. onwards another sample which was more infected had to be used. Since for each treatment there were five replications, the data for each temperature treatment was analysed separately by analysis of variance.

From the data in Table VI it may be seen that, excepting at '48°C. one hour pre-soaking', in all the remaining 59 treatments pre-soaking followed by hot water treatment lessened the disease significantly, but the reduction was considerable only at 61°C. and 62°C.; where the germination fell to 55 per cent. Only in four temperature treatments out of 15, the differences between the durations of pre-soaking were significant in respect of the disease. Pre-soaking for one hour seems to be almost as good as pre-soaking for four hours. Up to 58°C. there was no appreciable effect of durations of pre-soaking and of heat-treatment on germination. From 59°C. to 62°C., in general, higher temperature and longer pre-soaking up to three hours, reduced the germination. At this range the differences between three and four hours pre-soakings were negligible.

TABLE VI

Effect of pre-soaking and hot water treatment

Pre-soaking (a)	One hour		Two hours		Three hours		Four hours		Untreated		Critical difference	
Range 0°C.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.
48	88·2	13·9	90·8	9·7	91·9	9·1	90·1	9·6	87·4	14·9	Not significant	4·7
49	69·0	10·4	73·3	10·2	75·4	9·6	81·0	10·8	71·9	17·3	,,	4·8
50	88·0	12·9	87·6	15·1	88·7	10·8	83·9	9·1	86·4	23·1	,,	5·7
51	83·1	10·5	82·6	8·2	85·6	7·6	76·4	6·4	84·5	16·8	,,	5·1
52	79·4	11·6	79·0	10·0	79·8	9·5	80·3	9·5	82·3	21·0	,,	5·2
53	85·8	8·2	83·2	10·1	84·6	5·1	82·9	5·5	91·5	17·8	,,	7·4
54	88·2	10·3	88·8	8·4	88·9	8·3	90·1	9·9	90·6	17·3	,,	5·1
55	91·3	9·6	84·6	7·6	86·9	7·8	82·0	7·1	83·6	14·3	,,	3·9
56*	87·3	15·5	79·6	6·7	86·6	11·4	79·3	12·4	88·5	35·4	5·6	5·3
57	81·9	10·6	84·2	11·7	80·9	10·8	78·0	11·6	81·3	32·1	Not significant	3·6
58	85·8	14·5	82·3	11·9	75·2	14·5	75·7	15·3	79·9	33·7	,,	6·0
59	76·8	9·5	62·5	12·4	61·4	8·1	59·6	11·8	83·3	31·5	10·9	6·1
60	91·3	10·6	80·5	8·1	68·3	9·1	60·0	5·0	84·6	27·3	6·9	5·2
61	53·7	3·0	48·7	2·4	27·4	1·8	21·2	0·3	92·5	29·5	9·1	4·0
62	58·0	4·3	37·0	2·4	15·9	1·3	17·8	2·4	90·1	31·9	12·7	3·1

(a) =mean of 5 sets; G.P.=Germination percentage; D.P.=Disease percentage
*Sample of seed was changed at 56°C.

To locate a safe temperature range for the treatment, lethal temperatures for the seed, for the fungus in the seeds and for the sclerotial suspension were worked out by steeping these materials in hot-water ranging from 30°C. to 55°C. at intervals of 5°C., and thereafter at 1°C. interval till 70°C. The duration of the treatment was 15 minutes throughout. The data have been illustrated in Fig. 1. The viability of seeds was fairly steady till 57°C., thereafter it fell gradually till 63°C. when an abrupt fall occurred. In the fungal out-growths from the seed, there was a gradual decline from 45°C. to 54°C., and from 55°C. to 60°C. there was a steep fall. The zone for effective treatment appears to be between 55°C. and 60°C. Even at 70°C., 0·3 per cent of the seeds retained viable fungus. Since

temperatures above 56°C. proved lethal to pure sclerotial suspension, it seems that deep location within the seed helps the sclerotia in surviving higher range of temperature.

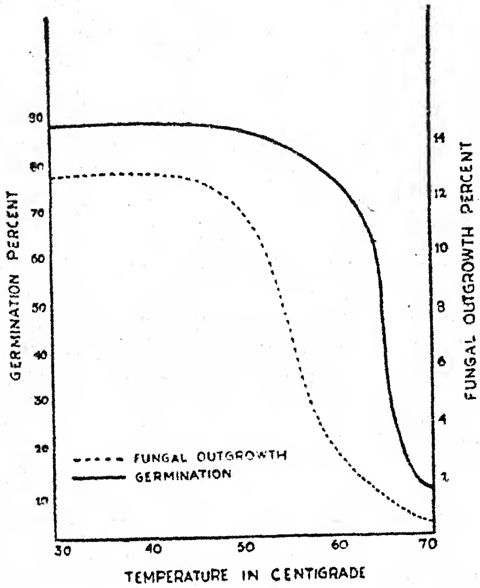

FIG. 1.

Chemicals. Seeds were treated in cold and hot solutions of formalin, mercuric chloride and copper sulphate for 15 or 20 minutes. Prior to treatment the air bubbles were forced out either under suction pump or by addition of 10 per cent castile soap. Four to five replications were given and the results obtained from plated seeds were analysed by analysis of variance (Table VII).

TABLE VII

Treatment of seed by liquid disinfectants

Treatment	Strength in percentage	Range in 0°C.	Duration in minutes	Mean		Remarks
				G. P.	D. P.	
Formalin	2	Cold	20	91·6	6·3	
	3	,,	20	89·5	7·4	
	4	,,	20	91·2	8·8	
	5	,,	20	91·0	4·6	
	6	,,	20	92·2	6·8	
Untreated	..	..	..	91·8	13·3	
Critical difference	..	..	..	Insignificant	5·0	
Formalin	2	52	20	62·1	1·7	Air evacuated from the chemical for the duration
	2	55	20	18·7	1·0	
	2	56	20	28·3	0·4	
	2	57	20	22·4	0·9	
	2	57	20	72·3	2·7	Air evacuated from water and chemical introduced
	2	60	20	37·0	2·7	

TABLE VII—*contd.*

Treatment of seed by liquid disinfectants—contd.

Treatment	Strength in percentage	Range in 0°C.	Duration in minutes	Mean		Remarks
				G. P.	D. P.	
Untreated	..	..	..	95·2	16·6	
Critical difference	..	..	..	14·6	2·9	
Formalin	1·5	55	15	49·8	9·8	Change of seed
	1·0	55	15	46·7	8·1	
	0·5	55	15	83·6	13·3	
Untreated	..	..	..	93·2	32·1	
Critical difference	..	..	..	7·7	8·1	
Mercuric chloride	0·1	48	20	71·5	12·4	
	0·1	50	20	67·7	11·2	
	0·1	52	20	81·7	11·3	
	0·1	54	20	73·8	4·1	
	0·1	56	20	72·4	3·4	
	0·1	58	20	33·4	1·0	
	0·1	60	20	24·1	0·5	
Untreated	..	..	..	93·0	24·1	
Critical difference	..	..	..	12·1	1·4	
Mercuric chloride	0·1	55	15	84·8	12·0	
	0·2	55	15	87·8	11·0	
	0·4	55	15	26·2	0·0	
	1·0	55	15	3·2	0·0	
	1·5	55	15	3·1	0·0	
Untreated	..	..	..	90·3	26·1	
Critical difference	..	..	..	6·0	3·4	
Copper sulphate	2	Cold	15	81·0	27·2	Change of seed
	5	,,	15	81·2	28·0	
	10	,,	15	87·9	26·3	
	15	,,	15	86·1	33·4	
Untreated	..	..	..	87·1	34·0	
Critical difference	..	..	..	Not signifi	cant	
No copper sulphate	..	55	15	91·1	11·7	
Copper sulphate	2	55	15	93·8	18·5	
	5	55	15	91·4	8·0	
	10	55	15	92·5	10·8	
	15	55	15	90·1	9·4	
Untreated	..	..	..	91·2	27·2	
Critical difference	..	..	..	Not significant	4·96	

G. P.=Germination percentage; D. P.=Disease percentage

That cold mercuric chloride has practically no effect on the seed fungus may be seen from Table VIII. Mercuric chloride when applied for 20 minutes at 54°C. or 56°C. reduces the infection, but also lowers the germination to 70 per cent (Table VII). Cold copper sulphate solution has no effect and, when applied hot, did not check the disease sufficiently. Hot formalin was quite effective in controlling the disease but lowered the viability of seeds. Of the three sterilants tried formalin, cold or warm, was the best.

The disadvantages of treatments with liquids are well known. Dusts are much more convenient to work with. Dusts of sulphur, naphthalene, copper carbonate and proprietory seed dressings like Ceresan, Nomersan and Agrosan G were compared with hot water treatments. In experiments I and II in Table VIII, the method used for dusting the seeds was defective and was modified in experiments III and IV, in which seeds were shaken with the dust for two minutes and the excess of dust removed by sieving. The first three experiments were conducted on potato-dextrose agar plates but the last one was carried out on sterilized sand in petri-dishes.

TABLE VIII

Comparative efficiency of various treatments

Treatments	Experiment I		Experiment II		Experiment III		Experiment IV	
	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.	G. P.	D. P.
Mercuric chloride 0·1 per cent (cold)	88·5	23·2	92·0	18·6	..	..	..	..
Formalin 5 per cent (cold)	91·8	17·4	80·7	15·7	..	..	..	..
Copper carbonate	93·8	23·1	90·2	20·2	..	..	..	..
Sulphur	..	..	..	..	96·0	21·2	..	..
Lime	..	..	..	..	92·5	22·5	..	..
Napthalene	..	..	..	..	88·7	13·3	..	..
56°C. for 15 minutes	..	..	..	..	..	..	91·0	6·5
57°C. for 15 minutes	..	..	..	..	..	..	81·6	6·5
58°C. for 15 minutes	..	..	..	..	..	..	86·4	8·0
Ceresan	83·2	3·1	68·9	3·1	89·3	0·6	92·0	1·0
Agrosan G	93·3	10·3	92·0	15·5	94·7	5·8	91·8	2·9
Nomersan	93·2	11·8	86·7	17·8	92·4	1·0	94·5	1·5
Untreated	91·9	24·2	90·3	21·8	96·7	22·8	88·6	16·9
Critical difference	6·3	8·0	8·2	5·6	3·2	2·7	7·4	3·8

Experiments I, II and III conducted on potato dextrose agar, experiment IV on sterilized sand in plates. G. P.= Germination percentage ; D. P.= Disease percentage.

Dusts of sulphur, lime, nephthalene and copper carbonate are not found efficient. Treatments with Ceresan, Nomersan and Agrosan G were quite effective and significantly better than hot-water treatments. These dusts when properly used did not hamper the viability of the seed.

These tests were extended to the field where in every season seedling mortality is a common feature. Counts of stand and seedling mortality were taken three weeks after sowing. The experiment was repeated on the same plots and data recorded, as per Table IX. As the differences in the stand were not significant, it suggests that the treatments did not have any phytocidal effect. Treatments with dusts and hot-water and the use of disease-free seed proved effective in checking the seedling mortality.

TABLE IX

Effect of seed treatment on mortality in field

Treatments	Experiment I		Experiment II	
	Stand	Mean disease per cent	Stand	Mean disease per cent
56°C. for 15 minutes	404	0·0	326	1·1
57°C. for 15 minutes	384	0·2	344	0·7
58°C. for 15 minutes	381	0·2	366	1·0
Ceresan	453	0·4	391	0·8
Nomersan	434	0·1	306	1·5
Agrosan G	403	1·2	373	0·8
Disease free seeds (untreated)	464	0·2	340	1·7
Control untreated	425	5·2	307	8·1
Critical difference	Not significant	1·07	Not significant	1·29

Layout—Randomized in six replications
Effective size of plot 3 ft. × 6 ft. Experiment I, sown on 2.5.42, Experiment II, sown on 26.6.42

In Table IX the disease in untreated control is rather low. In order to see whether the treatment of highly infected seed is more beneficial, a badly contaminated sample was compared with a

healthy lot of seed. Both the lots of seed were treated with Ceresan and planted in sterilized sand and incubated at 32°C. The data in Table X establish the usefulness of treating badly contaminated seed.

TABLE X

Seed treatment in relation to quality of seed

Quality of seed	*Mean G. P.		Mean D. P.	
	Untreated	Treated	Untreated	Treated
Diseased	59·8	61·2	75·4	5·5
Clean	94·3	83·2	2·9	0·0

*Mean of 12 sets each containing approximately 30 seeds.

Christensen and Stakman [1935] have similarly reported that the value of treating barley seeds against *Fusarium* and *Helminthosporium* depended upon the degree of seed infection. Obviously there is no use of treating clean seed.

Seed disinfection in relation to soil. It may be asked that since the fungus can be in the soil, what is the use of seed disinfection. To bring out the contrast between disease free and heavily infected soils, seeds treated with Agrosan G, Ceresan and Nomersan were grown in pots on sterilized and inoculated soils under green house conditions. There were ten replications. From the data in Table XI it may be concluded that both on inoculated and sterilized soils, the germination of seeds treated with Ceresan and Nomersan was significantly superior to that of untreated and Agrosan G treated seeds. The germination on the inoculated soil was generally lower but significantly so only in the case of untreated seeds. On sterilized soil the disease was significantly less in the case of treated seeds. On inoculated soil the disease was very high ranging from 93·0 to 95·8 and there was no difference between the treated seeds and the untreated ones.

TABLE XI

Seed disinfection in relation to soil

Condition of seed	Condition of soil	Treatment	Mean percentage of	
			Germination	Disease incidence
Diseased	Sterilized . .	Agrosan G . .	76·8	11·9
		Ceresan . .	87·7	2·3
		Nomersan . .	86·0	7·7
		Untreated . .	74·3	18·8
	Inoculated . .	Agrosan G . .	70·0	95·8
		Ceresan . .	80·0	93·0
		Nomersan . .	78·7	94·2
		Untreated . .	63·3	95·4
	Critical difference .	. . . . .	8·6	4·3

In the next experiment, field soil which is known to be infested with stem-rot was included along with sterilized and inoculated soil. Diseased and healthy seeds were used. Three hundred seeds were sown under each treatment and the pots were kept in a green-house. With a view to study the mode of initiation of the disease, the seedlings on which symptoms had just appeared were carefully uprooted and the seat of infection was located. The results are recorded in Table XII. On inoculated soil the disease is mostly initiated at the junction of the collar. While collar and radicle roots are associated with the soil infection, rots of cotyledon, hypocotyl, collar and radicle are associated with seed infection, but the aerial symptoms are predominant. On the field soil the use of disease-free seeds reduced the disease by nearly half, from 27·9 to 14·7 per cent. On sterilized soil, the use of diseased seeds yielded 16·3 per cent infection whereas with healthy seeds there was no disease. In this experiment the infection from the soil equalled that from the seeds and the seed infection had additive effect on the soil infection.

TABLE XII

Differences in seat of infection produced by the infected seed and soil

Condition of seed	Condition of soil	Discolouration at										
		Healthy	Cotyledon and seed-coat	Cotyledon	Hypo-cotyl	Junction (collar)	Radicle	Collar and radicle	Cotyledon and collar	Hypo-cotyl and collar	Percentage emerged	Percentage infection
Healthy	Sterilized (1)	252	..	..	..	..	..	..	..	..	84·0	0·0
	Inoculated (2)	6	..	..	..	200	28	24	..	..	86·0	97·6
	Field (3)	231	..	..	..	32	3	5	..	..	90·3	14·7
Diseased	Sterilized	154	5	6	8	5	2	..	2	2	61·3	16·3
	Inoculated	0	12	22	21	102	11	10	1	6	61·7	100·0
	Field	147	1	7	14	21	11	0	1	2	68·0	27·9

(1) Soil sterilized at 30 lb. pressure for one hour
(2) Soil inoculated with pure culture of *Macrophomina phaseoli* grown on jute seed sand media
(3) Field soil known to be infested with stem-rot fungus

Action of seed disinfectants. In experiments with dusts it was observed that on diseased dusted seeds hyphal growth was feeble despite the presence of sclerotia and mature hyphae within. This suggested the possibility of dusts inhibiting and retarding the fungal growth. With a view to test the action of the disinfectants on the disease, seeds treated in 0·1 per cent mercuric chloride for 10 minutes, Ceresan, Nomersan and Agrosan G were sown in sterilized test tubes on moist cotton wool. These conditions, i.e. high humidity and high temperature (28°C. to 30°C.), were favourable to the expression of the disease. Observations were made daily and seed rots, seedling rots and lesions on seedlings were recorded up to 10 days after sowing. In each treatment there were 400 seeds. From Part I of Table XIII it may be seen that Ceresan, Nomersan and Agrosan G were equally effective in controlling seed rots before the emergence of the seedlings. In preventing seedling rots, however, Ceresan and Nomersan were more effective than Agrosan G. Nearly half the seedling rots were due to the persisting contact of seed coat with the seedling. In untreated seeds the maximum of the seed rot is reached in two days after sowing whereas in dusted seeds this stage is not reached till six or seven days after sowing, vide part II of Table XIII. When the seeds were treated with Ceresan or Nomersan seedling rots hardly appeared till the fourth or the fifth day after sowing. This gave the seedlings a chance to establish.

TABLE XIII

Action of seed disinfectants

Part I

Treatment	Unviable No.	Pre-emergence mortality (seed rots per cent)	Per cent emerged	Post-emergence mortality (seedling rots)		
				Infection per cent due to seed coat adherence	Infection per cent not due to seed-coat adherence	Total percentage
Untreated	13	16·7	80·0	32·2	30·0	62·2
Mercuric chloride 0·1 per cent .	10	11·0	86·5	22·5	18·5	41·0
Agrosan G	15	4·5	91·7	10·3	11·5	21·8
Nomersan	11	5·2	92·0	2·4	4·7	7·1
Ceresan	11	4·7	92·5	2·4	3·2	5·6

Part II

No. of days after sowing	Percentages of pre-emergence and post-emergence rots at days after sowing									
	Untreated		Mercuric chloride		Agrosan G		Nomersan		Ceresan	
	Pre-emergence	Post-emergence	Pre-emergence	Post-emergence	Pre-emergence	Post-emergence	Pre-emergence	Post-emergence	Pre-emergence	Post-emergence
1	14·0	0·6	9·5	0·0	0·5	0·3	0·0	0·3	0·2	0·0
2	16·1	3·1	10·5	1·8	1·7	0·8	1·0	0·2	1·2	0·0
3	16·7	15·0	10·5	10·7	2·5	2·4	2·0	0·5	1·5	0·0
4	16·7	22·2	10·5	15·0	2·7	6·2	2·7	1·3	2·7	0·8
5	16·7	29·1	10·5	20·2	3·2	9·8	4·2	2·6	3·5	1·3
6	16·7	44·1	10·5	27·4	4·0	12·5	4·7	3·5	4·0	1·9
7	16·7	55·3	11·0	31·2	4·5	16·1	5·0	4·6	4·2	2·7
8	16·7	60·3	11·0	36·7	4·5	16·8	5·2	6·1	4·7	3·2
9	16·7	62·2	11·0	40·7	4·5	17·9	5·2	6·2	4·7	4·3
10	16·7	62·2	11·0	41·0	4·5	21·8	5·2	7·1	4·7	5·6

The untreated seeds and seeds treated with mercuric chloride had profuse hyphal growths. The seeds treated with Agrosan G exhibited slightly more of fungal growth than those treated with Ceresan and Nomersan. The three dusts in general yielded very feeble growths. In some cases, though the detached seed coats yielded fungal growths, the seedlings remained healthy. The low infection in Ceresan and Nomersan treated seeds may be due to their inhibiting action on the growth of the fungus directly under the seed coat.

DISCUSSION AND CONCLUSIONS.

Varada Rajan and Patel [1943] have shown that pycnospores released from diseased and infected seedlings cause secondary infection which is usually four times the primary one. Measures that can reduce the primary infection have therefore special importance. Three factors affect the primary infection, viz. (i) extent of seed infection, (ii) extent of soil infection, and (iii) the conditions under which the infection expresses itself and develops.

Taking the last factor first, it is found that little is known of the conditions under which the fungus expresses itself and develops in the field. Field observations on seedling mortality carried out at Dacca during 1939 to 1943 show that wet sowing seasons favour seedling mortality, particularly when contaminated seeds are used. During such seasons, primary lesions appear on all the serial

parts and collar, but the roots mostly remain healthy. The radicles on isolation do not yield any fungus though the soil is known to be infected. In dry seasons collar and root rots are frequent, but after a time the discolouration shreds and the seedlings recover. The mortality is therefore low in dry seasons.

In 1942 at the Dacca Farm, there was a long spell of dry weather accompanied by high temperatures. During this period seeds having about 30 per cent infection were sown in 18 in. pots containing infected field soil. They were kept in the open, but in one set high humidity was provided soon after sowing, in the second set after the germination was complete and in the third a fortnight after sowing. The control pots were exposed to the prevailing dry atmosphere. In each of the four treatments 400 seeds were sown. As soon as the symptoms appeared, each of the infected seedling was uprooted and the initial place of infection recorded. Chances for secondary infection were thus minimized.

TABLE XIV

Effect of humidity on disease expression

Conditions	Primary infection						
	Percentage emergence	Cotyledon	Hypocotyl	Root or collar	Exact position not clear but root healthy	Total No. infected	Percentage of infection
Pots exposed to atmospheric condition	89·7	3	5	12	3	23	6·0
Pots kept under high humidity after sowing	91·7	26	12	12	32	82	22·3
Pots kept under high humidity after complete germination	90·5	21	16	15	47	99	27·6
Pots kept under high humidity a fortnight after sowing—							
(a) before covering	92·7	3	4	11	..	18	4·8
(b) after covering	..	8	13	18	27	66	17·8

From the data in Table XIV it is apparent that high humidity quadrupled the primary infection. Under field conditions, the effect of humidity on infection will be much more pronounced as rotting seedlings will lie in the field and will produce abundant pycnospores. It is pertinent that excessive humidity increased aerial symptoms much more than the collar and root rots. This suggests that the fungus associated with the seed has played, under the conditions of the experiment, a more important role in the initiation of the disease than that associated with the soil. Andrus [1938] has found that any condition that favours the adherence of the infected seed coat to the seedling will favour infection. Observations have shown that excessive humidity favours the adherance of the seed coat.

It is not the intention to say that on all soils, infected seeds play the most important role in the initiation of the disease. When the soil is artificially inoculated, it is invariably found that the disease is much more than on sterilized soil with the infected seed. Results of six experiments tabulated below (Table XV) bear this out, but on infected field soils with which we have worked, the disease is not as high as in the inoculated soil. If the infection from the soil is really heavy, the health of the seeds should not affect the percentage of disease incidence. That this is not the case is borne out by three facts. Firstly, when healthy seeds are sown on infected field soil, the disease is consistently less than when diseased seeds are used. Secondly, comparing the performance of contaminated seeds on infected and sterilized soils, it is found that the disease on the former is not very much more than on the latter. Thirdly, when diseased seeds on sterilized soils are compared with the healthy seeds on the infected soil, it is observed that the former show more disease than the latter.

TABLE XV

Soil versus seed infection

Kinds of seed used	Percent of disease incidence in plants grown on various kinds of soils		
	Sterilized	Inoculated	Infected field soil
Diseased	18·8	95·4	..
Diseased	25·3	68·1	..
Healthy	2·3	39·1	..
Diseased	50·2	79·9	51·1
Healthy	2·1	71·4	31·3
Diseased	16·3	100·0	27·9
Healthy	0·0	97·6	14·7
Diseased	39·3	83·2	43·9
Healthy	0·0	73·2	14·5
Diseased	30·5	87·0	41·2
Healthy	1·3	94·6	29·2

Surveys have shown that crop stubbles showing viable sclerotia occur rarely in lands that are inundated, sporadically in midlands, and considerably in high lands. The infected soil used in these experiments was from high lands of the Dacca Farm where the disease appears every year in considerable proportion. The authors have only once come across the disease in a more intense form than that at the Dacca Farm, and that was in mid-lands near Narsingdi. On low lands where the soil infection is negligible, considerable seedling mortality has been observed and this has been linked up with the use of infected seeds. At the sub-station at Konda, which is inundated every year, it is a common experience to find heavy seedling mortality in plots raised from Dacca seeds, whereas plots from locally collected seeds are practically disease free.

Amongst the methods tried for the disinfection of seeds, hot water treatment and seed-dressing proved effective. The latter is simple and is capable of wider use. Of the three dusts, Ceresan has consistently given better results, Nomersan being a close second. Agrosan G is clearly not as effective as Ceresan and is inferior to Nomersan. To facilitate comparison the relative performance of these three fungicides has been compiled in Table XVI. It is suggested that superiority of Ceresan and Nomersan over Agrosan G is due to their preventive action on post-emergence mortality.

TABLE XVI

Relative efficiency of seed dressings

Seeds grown on	Percentage of disease in seeds treated with			
	Ceresan	Nomersan	Agrosan G	Control
Potato dextrose agar in plates	0·6	1·0	5·8	22·8
On cotton wool in sterilized tubes	5·6	7·1	21·8	62·2
On sterilized sand in plates	1·0	1·5	2·9	16·9
On sterilized sand in plates	5·5	..	..	75·4
On sterilized soil in pots	2·3	7·7	11·9	18·8
Soil in fields	0·4	0·1	1·2	5·2
Soil in fields	0·8	1·5	0·8	8·1

Summary

Transmission of the stem rot disease of jute through the seeds has been demonstrated. Mature hyphae and sclerotia of the fungus *Macrophomina* are borne on and within the seed. The mode of infection of seeds and the technique for its detection have been described. This contamination of the seeds lessens germination and initiates primary infection. It is suggested that under ordinary conditions the role of the seeds in the initiation of the disease is more important than that of the soil. In heavily infected soils the use of disease-free seeds is of no avail in combating the disease, but such soils are rare. High humidity favours the development of the disease on seedlings as well as on seed-capsules.

For destroying the pathogen without affecting the viability appreciably, heating the seeds in water proved more useful than heating them in air. The zone for effective treatment appears to be between 55°C. and 60°C. Sclerotia that are located deep in the seed may survive even at 70°C. In activating the hibernating fungus, pre-soaking of seeds did not assist much.

Amongst the various chemicals tried, Ceresan, Nomersan and Agrosan G proved effective as seed disinfectants. Ceresan and Nomersan appear to be superior to Agrosan G. All the three can control seed rot, but Agrosan G is not as effective as the other two in preventing seedling rot.

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STUDIES ON THE VIRUS DISEASES OF POTATOES IN INDIA

III. OCCURRENCE OF SOLANUM VIRUS 3. MURPHY AND M'KAY

By R. Sahai Vasudeva, Plant Pathologist, and C. S. Ramamoorthy, Assistant, Division of Mycology and Plant Pathology, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 28 September 1945)

(With Plate XX)

During the course of observations on the incidence of virus diseases of potatoes in the mycological area of this Institute, *Solanum Virus* 3 (Potato Virus A) was recovered from potato plants of *Phulwa* variety showing yellowing of the leaf margins or deep yellow brilliant mottle. The virus was also recovered from potato plants of variety *Darjeeling Red Round* which showed crinkling of leaves. The types of symptoms exhibited by plants from which the virus was recovered are described below.

Type 1. In *Phulwa* variety yellowing of the margins of the leaves was uncommon and only one plant showing such symptoms was observed in the whole area. When first observed the tips or the margins of some of the young leaflets exhibited yellow colouration. With age the yellowing became more pronounced covering larger portions of the margin and its progress inwards was limited by the minor veins while the dark green colour persisted in the central region. Some of the leaflets however, turned completely yellow. About two months later small circular necrotic spots appeared and gradually their number increased (Plate XX, fig. 1).

Type 2. The plants of *Phulwa* variety which exhibited yellow spots were different in that the young shoots on their emergence did not show yellow spots but after several weeks growth small yellow areas were observed on the old as well as the young leaves. The areas were irregular in shape and quickly assumed characteristic deep yellow colour. Frequently such areas merged to form

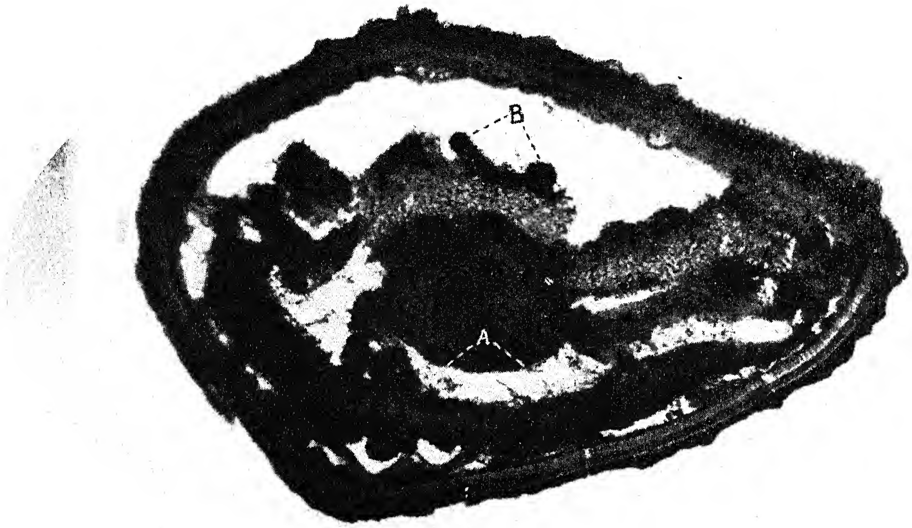


FIG. 1. A. Mycelium; B. Sclerotial bodies (×60)
A transverse section of Jute seed (D154)

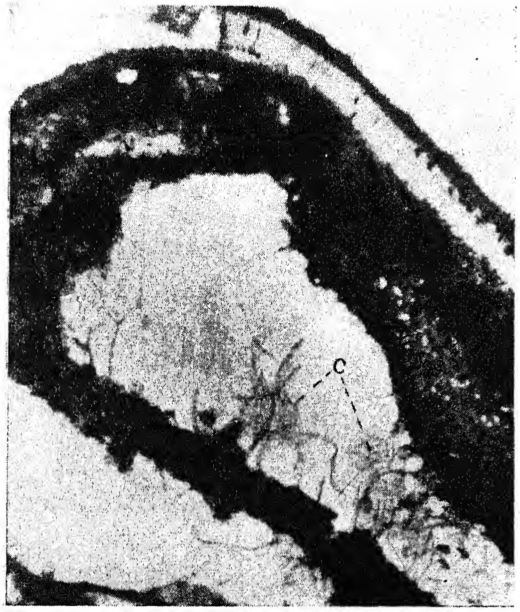


FIG. 2. C. Mycelium within the cotyledons (×300)

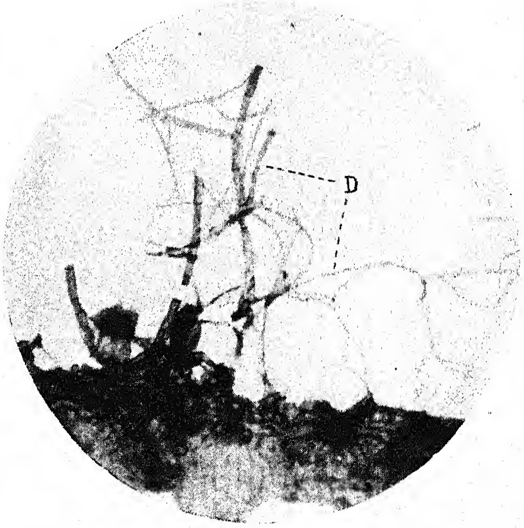
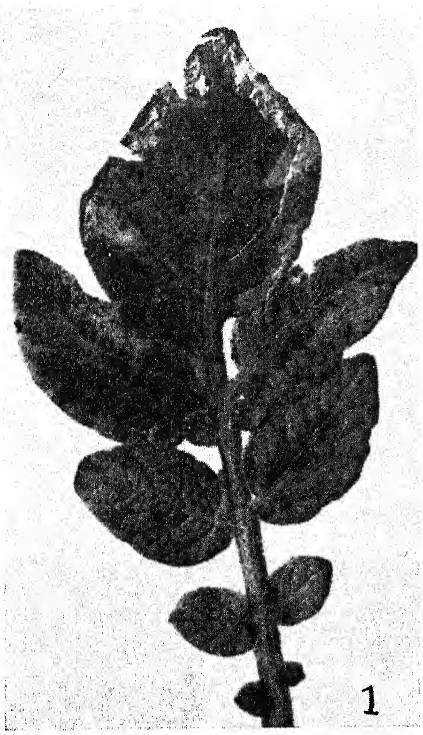
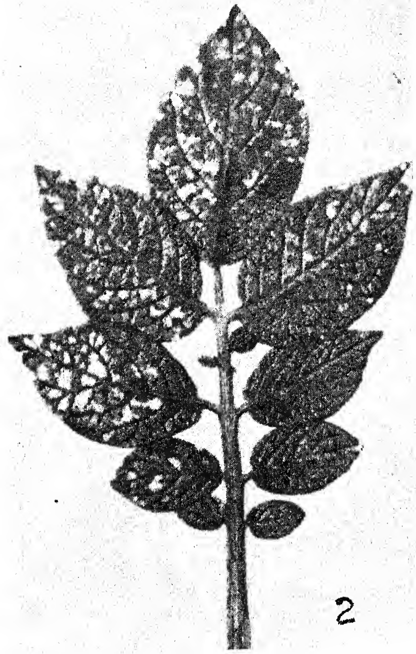
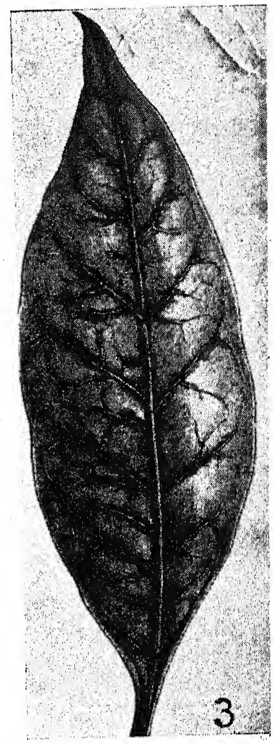
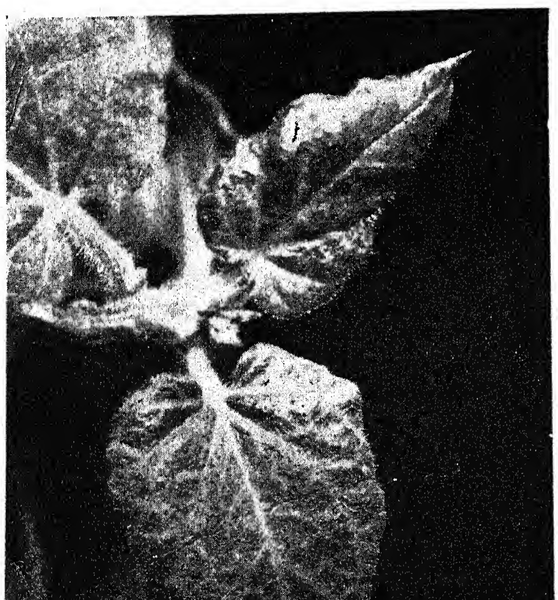


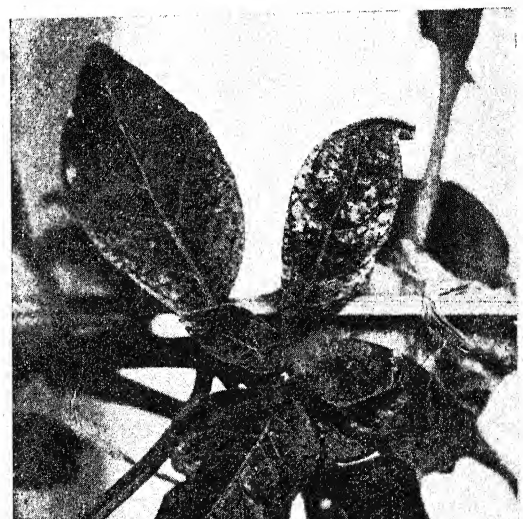
FIG. 3. D. Hyphal growths (×500)











Figs. 1 and 2. Leaflets of potato plants of *Phulwa* variety showing yellowing of the margins and yellow spots respectively
Fig. 3. *Nicotiana tabacum* showing green vein-banding
Fig. 4. *Nicotiana glutinosa* showing thickening of veins
Fig. 5. *Datura stramonium* showing yellow mottle after grafting with infected potato plant

larger areas. The yellowing was not accompanied by any other symptom except slight puckering occasionally. The plants raised from tubers of such plants for the last two years exhibited similar symptoms (Plate XX, fig. 2).

Type 3. In another lot of *Phulwa* plants small bright yellow circular or oval mottle was observed on the lower leaves of very young plants. As the plants advanced in age no additional spots appeared.

Type 4. The virus was also recovered from *Darjeeling Red Round* plants showing stunting and extreme puckering with downward curving of leaves. Diffused pale areas occurred all over the surface of the leaves. The colour of the foliage in general was pale green and the leaflets were brittle and could easily be damaged and detached from the plant.

Preliminary testing for host range was limited to a number of plants of the Solanaceae which are usually used for the identification of viruses. For these tests inoculations with standard extracts of *Phulwa* potato plants showing three types of symptoms and from *Darjeeling Red Round* plant showing crinkle were carried out. Wherever necessary grafts on some of the solanaceous plants and potato varieties were made by the cleft method.

The standard extract for inoculation purposes was prepared by crushing to a fine pulp in pestle and mortar a known weight of young infected leaves which had previously been washed and dried in folds of filter paper adding a small quantity of sterile distilled water at a time. To every gram of leafy material 1 c.c. of water was added. This material was then pressed through fine muslin by hand.

Inoculations were carried out by dusting the leaves, held in position over a piece of cardboard, with finely powdered carborundum and smearing the leaf with a piece of absorbent cotton wool dipped in fresh standard extract from the diseased plant. Controls were always maintained side by side. Every precaution was taken to maintain aseptic conditions and all the apparatus used was sterilized as considered necessary for each experiment.

All the experimental work was carried out in an insect proof house and transmission tests were conducted both by mechanical means and by grafts as required in individual cases. In order to provide a stock of freshly infected plants for inoculation work the culture of the virus was maintained on young tobacco plants. The plants raised in sterile soil under insect proof conditions were as a rule inoculated when they had developed the first two to four true leaves and for any one experiment plants of the same age were employed. The test plants were always kept under observation for at least three weeks.

The reactions on differential hosts in all the four types indicated the presence of Virus A. *Phulwa* type 2 in addition indicated the presence of a weak strain of Virus X and the presence of a weak strain of this virus was also suspected in potato plants of variety *Darjeeling Red Round* exhibiting crinkle. Presence of Y Virus was indicated during one set of transmission experiments in *Phulwa* type one. These observations suggested the presence of the following Viruses.

Phulwa group 1 A+Y (*Solanum Virus* 3+*Solanum Virus* 2)
Phulwa group 2 X+A (*Solanum Virus* 1+*Solanum Virus* 3)
Phulwa group 3 A (*Solanum Virus* 3)
Darjeeling Red Round—Crinkle A+X (*Solanum Virus* 3+*Solanum Virus* 1)

The reactions on differential hosts and physical properties of Virus A which occurred commonly were studied in detail in order to confirm the identity of the virus. The culture of the virus recovered from *Phulwa* group 1 was used in these experiments.

Reactions on differential hosts

Nicotiana tabacum *L. variety* White Burley. Ten days after infection faint vein clearing is observed on younger leaves and within two weeks it is followed by green vein-banding on older leaves. On tobacco variety *Harrison's Special* similar but highly pronounced symptoms were observed (Plate XX, fig. 3).

Nicotiana glutinosa L. Infected plants show a peculiar tendency for the veins to thicken but with age the symptoms disappear (Plate XX, fig. 4).

Datura stramonium L. (*Jimson weed*). This plant could not be infected by mechanical inoculation but when shoot from the infected potato plant was grafted, the axillary shoots exhibited disease symptoms. In early stages slight pallor of the leaves was observed but this was followed by yellow speck-like mottle which usually commenced at the tip of the leaves. With the development of the leaves the symptoms became more pronounced and yellow areas interspersed with small green areas were observed. There was no necrosis (Plate XX, fig. 5). Efforts to transmit the disease from infected plants of *Datura stramonium* to healthy *Datura* plants by needle inoculation were unsuccessful.

Solanum nodiflorum Jacq., *Nicotiana rustica* L., *Petunia hybrida* Vilm and *Solanum nigrum* L. were not affected by the virus.

When infected shoot of *Phulwa* potato plant was grafted to virus free *President* potato plant it developed chlorosis and pale yellowish mottle but no deformity of the leaf was observed.

Properties of the virus

Exposure of the virus for ten minutes in a water bath at different temperatures shows that the activity of the virus is considerably reduced at 50°C. and that the thermal inactivation point lies between 50°C. and 55°C. The virus begins gradually to lose its activity at a dilution of 1 : 10 and becomes innocuous at a dilution of 1 : 200. The virus also begins to lose its activity after storage for 24 hours at room temperature and at 12°C. In the former case it entirely loses its activity after 48 hours of storage.

The reactions on differential hosts and the properties show that the virus described is *Solanum virus* 3 Murphy and M'Kay.

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FURTHER OBSERVATIONS ON THE EFFECT OF FROST ON SOME ECONOMIC PLANTS OF DELHI

By Harbhajan Singh, M.Sc., Assoc.I.A.R.I., Imperial Agricultural Research Institute, New Delhi

(Received for publication on 29 October 1945)

IN January, 1942, Delhi experienced a severe frost, resulting in damage to a wide variety of plants. The author then made some observations on the effect of frost and the information thus collected was recorded in a note published in a previous issue of this Journal [Singh, 1943]. References to previous records of frost damage were then made and are not repeated here.

During the winter of 1945, Delhi was again under the spell of a severe cold wave, experiencing several frosty nights; at times three to four such nights occurred in succession. The more severe frosts occurred during the first fortnight of January and on the night of January 12, a minimum temperature of 30°F. was recorded at the Imperial Agricultural Research Institute, New Delhi (the minimum temperature of 1942 was 28·3°F.). Though there were repeated attacks, the frost of 1945 was milder than that of 1942. This may have resulted in natural 'pre-hardening' of the vegetation

to some extent. It is possible, the damage would have been much more pronounced if the weather preceding the frost had been warm like that of 1942.

The relevant temperature and humidity data are given in Table I.

TABLE I

Minimum and maximum temperatures and humidity recorded at the Imperial Agricultural Research Institute, New Delhi, from the 1st to 15th January, 1945

Date	Temperature (°F.)		Humidity	Date	Temperature (°F.)		Humidity
	Maximum	Minimum			Maximum	Minimum	
1	53·4	39·0	96	8	59·0	38·5	96
2	61·4	35·5	91	9	59·5	47·0	93
3	60·3	38·0	98	10	58·6	48·0	92
4	56·0	45·2	83	11	52·6	34·8	100
5	52·8	47·0	98	12	53·8	30·0	90
6	55·4	36·6	99	13	55·2	31·8	90
7	55·8	36·0	100	14	60·8	34·2	95
				15	63·5	37·0	95

It may be pointed out that all the plants mentioned in the present note are not local. At the Section of Economic Botany of the Imperial Agricultural Research Institute, New Delhi, a living collection of important wild and cultivated plants both indigenous and exotic is being maintained. It is mainly this material which forms the subject matter of this note.

Table II gives the names of plants observed for resistance or susceptibility to a temperature of 30°F. with brief notes on the nature of the damage.

TABLE II

List of plants with remarks on their resistance to frost

English or Indian name	Botanical name	Stage of the plant	Effect of frost
	Solanum ferox L.	Fruiting	Highly resistant.
	Solanum indicum L.	Just before flowering	Fairly susceptible. In a week's time new axillary shoots appeared.
Bari kateli	*Solanum incanum* L.	Fruiting	Fairly susceptible. Leaves were damaged.
Kateli	*Solanum xanthocarpum* Schrad & Wendl.	Fruiting	Fairly susceptible. Leaves were damaged.
	Solanum torvum Swartz	Fruiting and flowering.	Leaves of the upper branches were affected. Green fruits got shrunken.
Black Nightshade, *makoh*	*Solanum nigrum* L.	Fruiting	Fairly susceptible. Leaves and growing buds were damaged.
Currant tomato	*Lycopersicon pimpinellifolium* Mill.	Flowering and fruiting.	Leaves highly susceptible. Ripe and unripe fruits were very little affected.
	Lycopersicon hirsutum H. B. & K.	Flowering	Leaves and tender stems highly susceptible.
	Lycopersicon peruvianum Mill.	Flowering and fruiting.	Leaves and tender stems most affected. Fruits slightly affected.
Gooseberry, *rasbhari*	*Physalis peruviana* L.	Fruiting	Slight effect on leaves. The enlarged calyx of the fruit developed brown patches.

N

TABLE II—*contd.*

List of plants with remarks on their resistance to frost—contd.

English or Indian name	Botanical name	Stage of the plant	Effect of frost
Vegetable rennet	*Withania Coagulans* Dun.	Leafy	Highly resistant
Thorn apple, *safaid datura*	*Datura fastuosa* L.	Fruiting	Leaves badly damaged. Brown patches appeared on the green fruits.
Thorn apple, *kala datura*	*Datura fastuosa* L. var. *tatula*	Fruiting	Leaves badly damaged. Fruits had already ripened.
	Crotalaria retusa L.	Flowering and fruiting.	Leaves, flowers and buds were damaged.
	Crotalaria sericea willd.	Do.	Highly resistant
	Crotalaria striata Dc.	Do.	Highly susceptible
	Crotalaria anagyroides H. B. & K.	Just before flowering	Highly resistant
	Desmodium gyroides Dc.	Leafy	Leaves of top-most branches affected.
"Avaram bark"	*Cassia auriculata* L.	Leafy	Highly susceptible. New shoots appeared later.
Isafgol	*Plantago ovata* Forsk.	Leafy	Highly resistant
"Fleawort"	*Plantago psyllium* L.	Leafy	Do.
	Plantago lanceolata L.	Do.	Do.
	Plantago amplexicaulis cav.	Do.	Do.
Buckwheat	*Fagopyrum esculentum* Moench	Flowering	Highly susceptible. The top portions of branches with leaves and young flower buds were damaged. The plants resprouted.
Celery	*Apium graveolens* L.	Leafy	Highly resistant
Aramina	*Urena lobata* L.	Flowering and fruiting.	Leaves were completely frosted. Fruits had already matured.
Jangli bhendi	*Hibiscus ficulneus* L.	Flowering	Highly susceptible
Tukham malangan	*Lallemantia royleana* Benth.	Leafy	Highly resistant
Venezuela grass or Molasses grass.	*Melinus minutiflora* Beauv.	Leafy	All the aerial parts were severely damaged. The plants were cut back to the ground level and fresh growth appeared after about a fortnight.
Rye	*Secale cereale* L.	Vegetative	Highly resistant
	Aegilops ventricosa Tausch.	Do.	Do.
	Aegilops triuncialis L.	Do.	Do.
	Aegilops squarrosa L.	Do.	Do.
	Agropyron cristatum Boiss.	Do.	Do.
	Bromus japonicus Thunb.	Do.	Do.
Rescue grass	*Bromus unioloides* H.B.K.	Do.	Do.
	Phalaris minor Retz.	Do.	Do.
Wild barley	*Hordeum murinum* L.	Do.	Do.
Two-rowed wild barley	*Hordeum distichon* L.	Do.	Do.
Rye-grass	*Lolium temulentum* L.	Do.	Do.
Perennial rye-grass	*Lolium perenne* L.	Do.	Do.

SUMMARY

Data regarding minimum maximum temperatures and humidity from the 1st to 15th January, 1945, as recorded at the Imperial Agricultural Research Institute, New Delhi, are given.

The effects of frost on a number of plants, both indigenous and exotic, maintained at the Section of Economic Botany of the Institute, are recorded.

ACKNOWLEDGEMENT

The author is grateful to Dr B. P. Pal, Imperial Economic Botanist, for providing the necessary facilities in the compilation of these notes and also for suggesting several improvements.

REFERENCE

Singh, Harbhajan (1943). Effect of frost on some economic plants of Delhi. *Indian J. agric. Sci.* 13, 279-82.

REVIEWS

. The constituents of wheat and wheat.products

By C. H. Bailey (Published by *Reinhold Publishing Corporation, New York, 1944*) *pp. 332 Price $6·50*)

THOUGH it is great privilege to be asked to review such a book, the undersigned feels rather shy in passing any judgement on this great book written by the great man Dr C. H. Bailey who is considered to be an outstanding cereal chemist of the world and a leader in this field of science. It was from him that the reviewer acquired the knowledge of cereal chemistry and technology while he was his student in the University of Minnesota, U. S. A., sometime ago.

After going through the book one may be inclined to feel that it contains details of numerous items which may be only of a historical interest. Whilst this may be true, the important point to be taken into consideration is the masterly grasp of the subject and the painstaking thoroughness with which Dr Bailey has brought together, in a systematic and readily available form, the enormous literature which has accumulated mostly during the past half century, beginning with Becarris famous "glutan working experiments", published as early as 1745. The reviewer is sure all the cereal chemists and technologists will gratefully acknowledge the real service that Dr Bailey has done to them by placing before them such a comprehensive and unique compilation which is designed to serve as a guide and source of reference to the complex and massive literature on wheat chemistry.

Every cereal chemist and technologist will wish to own a copy of such an excellent book, which happens to be the first and the only one of its kind that has so far been written.

The book contains 16 chapters of which seven deal with the nitrogenous compounds and three with carobohydrates. The remaining six are devoted, respectively, to the liquids, minarals halogens (together with sulphur and selenium), acidity, pigments and vitamins.

Dr Bailey has given a hint in his introduction that he is planning to bring out a second volume which will deal with the dynamic biochemistry of wheat dealing with, among other things, enzymes, bread making, wheat processing, etc. There is no doubt that such a book will get enthusiastic reception and these two volumes, this and the one which Dr Bailey contemplates publishing, will form the *vade macum* of the cereal chemist.

There is a complete list of references at the end of each chapter, the total number of citations being 1024. The book contains an author index and an adequate subject index.—R.S.

PLANT QUARANTINE NOTIFICATION

Notice No. 5 of 1945

THE following quarantine regulations have been received in the Imperial Council of Agricultural Research. Any one interested is advised to apply for detailed information to the Secretary, Imperial Council of Agricultural Research, New Delhi.

1. B.E.P.Q.—396, Supplement No. 2, dated 6 July 1945 issued by the United States Department of Agriculture.
2. B.E.P.Q.—379 (Revised), Supplement No. 2, dated 30 June 1945 issued by the United States Department of Agriculture.
3. B.E.P.Q.—502, Supplement No. 1 Revised dated 30 June 1945 issued by the United States Department of Agriculture.
4. B.E.P.Q.—416, Revised, Supplement No. 1, dated 7 August 1945 issued by the United States Department of Agriculture.

MGIPC—M—III-1-10—31-3-47—600.

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(June 1946)

The Editorial Committee of the Imperial Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal

Original articles—

ERRATA

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263	9	*For the word*	"adaptablity"	*substitute the word*	adaptability
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267	4 (below TableV),	,,	"Chorizons"	,,	C horizons
284	last	,,	"106./25 ft."	,,	106.25 ft.

Ind. Jour. Agr. Sci. XVI June. 46.

ORIGINAL ARTICLES

THE MEASUREMENT OF SOIL EROSION

I. THE ERODIBILITY OF SOME BENGAL SOILS UNDER BARE FIELD CONDITIONS

By A. T. Sen, M. Sc., Ph. D. (Lond.), A. I. C. and A. K. Dutt,
Agricultural Chemistry Section, Dacca University

(Received for publication on 28 March 1944)

(With one text-figure)

General introduction

Virgin soils under natural vegetation suffer no appreciable erosion by water or wind, excepting of course the slight geological erosion. The latter, however, is beneficient to soil formation. It is thus obvious that erodibility is not an inherent property of any virgin soil. Only when the vegetation is removed that soils become unstable and more so in countries of rolling topography. Instances of vast areas losing the whole of their top soil, the most fertile portion, within a few years through man-accelerated erosion, are frequent. In fact, soil erosion has become a national problem in almost every country It is, therefore, increasingly realized that the progress of erosion must be checked. Consequently, efforts, large or small, are now being made in this direction in almost every country. It is hardly necessary to stress that such efforts to be successful must be based on the information obtained on the erodibility of soils in the bare condition.

Information about erodibility of soils is usually obtained through elaborate field experiments. Unfortunately, the information so obtained relates to the particular environmental conditions which might have prevailed during the course of those experiments. This puts considerable limitation to the value of soil erosion measurement. Nevertheless, such measurement has given many useful data. The drawback in the field experiment is that it is both expensive and time-consuming. If similar information can be obtained much more quickly and at a very low cost by any other technique, the value of the latter becomes obvious. Already certain indications have been obtained by one of us [Sen, 1939] that the laboratory measurement of soil erosion may prove to be such a technique.

The purpose of the present series of investigations is to examine the scope of that technique with a view to eventually employing it in any comprehensive anti-erosion projects. It may be said at once that where anti-erosion project is of immediate necessity, the field technique is altogether out of the question. Something has got to be found which may be capable of defining slope classes quickly.

In the present investigation the technique has been tried on Bengal soils only. These soils are mostly alluvial in character and have been deposited in the plains from the gradual washings of the mountains, and are rather young. They are generally liable to erosion when kept bare of vegetation, since they lie in a region of heavy storms.

The investigation has been carried out as follows:

Part I. The erodibility of some Bengal soils under bare field conditions.

Part II. The erodibility of some Bengal soils under laboratory-controlled conditions.

Part III. Certain physico-chemical properties of some Bengal soils as related to their erodibilities.

Part IV. The effect of organic matter and lime on the erodibility of Dacca red loam.

Appendix. A method for measuring the dispersion ratio of Indian red and laterite soils.

I. The erodibility of some Bengal soils under bare field conditions

The field measurement of soil erosion has been carried out mostly in America. Excepting the works of Gorrie [1937; 1938] and that of Kanitkar, Daji and Gokhale [1941], no detailed record of measurement of erosion in the field is available in India.

Kanitkar, Daji and Gokhale [1941] conducted erosion experiments at Sholapur, Bombay. They studied the effect of intensity and distribution of annual rainfall on erosional behaviour of soils derived from the Deccan trap and belonging to the Chernozem group. The previous moisture status of the soil was found to influence the occurrence and extent of runoff very greatly. They also estimated the amount of soluble salts removed from soils in runoff, lime forming a considerable proportion of such losses.

Sir Archibald Geikie has mentioned in his Text-book of Geology the huge figure of 356.3 million tons of solid matter as being lost from the land by the Ganges during a single year.

The amount of rainfall lost as runoff has been measured by several workers. In America the work of Mosier and Gustafson [1918] over a period of three years shows that there is marked seasonal variation in percentage runoff which varies from 31 to 50 per cent of the annual rainfall. A runoff varying from 5 per cent in the case of plots covered with grass and shrub, to 25 per cent of a bare soil has been recorded by Gorrie [1938] in India. He further finds that nearly 8 tons per acre of soil are lost from a bare plot during a single monsoon. In Russia [Jacks and Whyte, 1938] the average soil losses vary from 20 tons per hectre per annum on gentle and moderate slopes to 50 tons on steep slopes. In Ceylon, Holland and Joachim [1933] observe that, under current estate practices, the soil loss by erosion varies from 56 to 101 tons per acre during a period of six years. Dickson [1929] has observed very heavy erosions with an average annual rainfall of only 21.68 inches. Lowdermilk [1931] finds a correlation between runoff and intensity of rainfall. On the other hand, Conner, Dickson, and Scoates [1930] have failed to establish any direct relation between erosion and intensity of rainfall. They observe, however, that runoff is influenced by the moisture content of the soil. Horton [1933] recognizes the importance of the moisture content of the soil and divides storms in two classes on the basis of their occurrence in relation to previous rains. Neal [1938] has shown that the moisture content of the soil at the time of precipitation is the most important factor determining the amount and rate of infiltration. As infiltration decreases runoff increases.

As regards the amount of nutrients removed in the process of soil erosion, Middleton [1932] observes that the severe result will be a loss of nitrogen, phosphorus and organic matter. According to Duley and Miller [1923] the losses in some cases are greater than the annual crop requirements.

The purpose of this paper is to obtain information regarding the relative erodibilities of some of the Bengal soils lying in the erosion-affected regions, and, incidentally, regarding the probable annual loss of soil material and fertility elements occurring in those soils when kept bare of vegetation. As the field measurement calls for elaborate arrangement which was beyond our means we were forced to adopt a simplified technique for measuring the erosion in small bare plots under short storms. Eight different places, distributed over Bengal, were selected. Two soils at each place had thus been examined. The results of the field measurement have been compared here with those obtained for the same soils in the laboratory under more controlled conditions (Part II of this series), so as to see if the latter could be exploited to advantage.

EXPERIMENTAL

A wooden bottomless box, 18 in. × 18 in. × 8 in., provided with 1 in. wide gutter along one side and 2 in. below the upper edge of the side, has been used for erosion measurement. The gutter is made slightly sloping to facilitate a free passage of the runoff along with the eroded soil in order to prevent the over-flow of the runoff which otherwise may be caused by the accumulation of the eroded material. An outlet tube kept flush with gutter is also provided.

A suitable open site is selected and carefully denuded of the natural vegetation (grass) by means of a flat trowel, disturbing the soil as little as possible. The slope of the land is then found out as follows: One end of a scale, 50 cm. long, is allowed to rest on the soil and the other end is slided up and down against another small scale held vertical, until a spirit level placed on the long scale indicates that the scale is horizontal. The vertical drop at this end of the scale is then directly read off from the small scale. This multiplied by 2 gives the per cent slope of the land.

At the site selected the box is placed and its inner boundary marked with a knife. The box is removed and the marked space is then completely covered with a metal plate. The object of the cover is to protect the surface soil from being disturbed during digging. With the cover kept in position, the ground around it is dug with a pick-axe to about the depth required for setting the box, care being taken that the pit so dug around the boundary is as narrow as possible. The box is placed in position and sunk by removing the extra earth from the sides with a '*Khanta*'. Where boulders appear as at Duars and Sukna and as they are likely to obstruct the sinking of the box, they are very carefully removed and the space is filled with the top soil; care being taken that when the box is sunk the gutter sets flush with the soil. The metal cover is then removed and any small gaps along the inner edges of the box are filled up with the top soil up to the surface level.

When the box has been fixed in position a bent glass tube is fitted through a hole at one end of the gutter by means of sealing wax. The other end of the bent tube is connected by a rubber tube with another glass tube leading through a rubber cork into a reservoir in which the runoff with the eroded material is collected. An air passage is provided for the reservoir by another glass tube through the rubber cork. All joints are then tested for leakage of water.

A rain gauge is placed nearby on land made level by scraping with the '*khanta*' and held firmly in position by means of wooden sticks fixed in the earth.

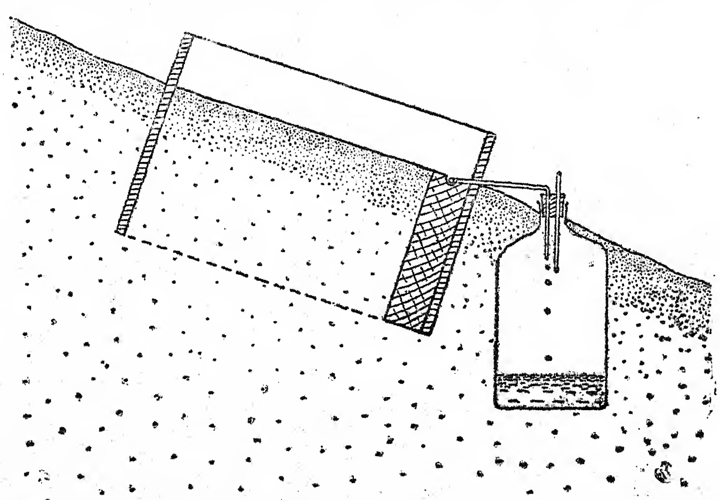

FIG. 1. Complete arrangement of the apparatus as installed at site

After the box has been installed, a few samples of the undisturbed soil are taken at random by a borer in the immediate neighbourhood outside the box to determine the moisture content before rainfall and the soil's mechanical composition.

After a shower, the eroded soil still left in the gutter is washed into the reservoir with a policeman, using a portion of the collected runoff by means of a pipette. The volume of the runoff is then measured and this along with the eroded soil is sent to the laboratory, where the eroded material is filtered, dried at 100—105°C. and weighed. The nitrogen in the eroded material is estimated by the modified Kjeldahl's method and the available phosphate by the Troug's method [Wright, 1939].

Effect of slope and soil characters

In Table I the rainfall, the runoff and the soil loss during experiment together with the name of the locality, soil number as well as its moisture content before rainfall, and other data are given.

All the soils, excepting 5A and 6A, show considerable erosion even under such light showers as 0.2—0.3 in. in some cases. Of the total precipitation received during experiment, 21 to 76 per cent of it has been lost as runoff (column h). The Durgapur (5A & 6A) soils, in which no runoff and soil-loss have occurred, are almost dry at the time of the experiment, and they have absorbed the whole of the shower of 0.45 in. as quickly as it has fallen. It will be further seen that the Bolpur (15A and 16A) soils are also similarly dry, and the amount and intensity of rainfall (columns c and e) are more or less identical with those in the case of Durgapur soils, yet there have occurred considerable runoff and soil losses (columns f and g). This difference in the erodibility between the Durgapur and Bolpur soils is partly due to the slope differences and partly to the difference in the mechanical composition of the soils of the two places. The Durgapur soils are highly sandy containing approximately 91 to 95 per cent sand, while the Bolpur soils are loamy containing about 35 to 40 per cent of clay plus silt (column k).

Comparative erodibility of the soils. If the soils, 2A, 8A, 10A and DF, the slopes of which are more or less equal are compared, it will be seen from columns (f) and (g) that both the runoff and soil loss of DF are very much greater than those of 2A, although the amounts of rainfall in the two cases are almost equal. The runoff and soil loss of 10A soil are minimum amongst the four soils compared. This, however, may be due to the much smaller precipitation in this case. In order, therefore, to bring the soil losses of all the soils on a comparative basis, the soil-loss in grams per 1000 c.c. runoff have been calculated and are given in column (j). It will be seen that the soil-losses in the case of the four soils are 5.29, 9.9, 12.98, and 18.19 gm. per 1000 c.c. runoff for 10A, 2A, 8A and DF soils respectively. In other words, the erodibility of the DF soil is roughly thrice, twice and one and half times as much as that of 10A, 2A and 8A respectively. On the other hand, even for the soils within the same locality, such as 3A and 4A, where, excepting the slope, all other conditions are same, the 4A soil at a lower slope has eroded more than the 3A soil at a higher slope.

It has already been pointed out that no runoff has occurred in the case of the almost dry Durgapur soils, 5A and 6A. Again, for the Sukna soils 9A and 10A, much greater runoff (column f) has been obtained for the 10A soil at a lower slope than that of 9A soil at a higher slope. The higher moisture content of the 10A soil may have partly caused a greater runoff. Similarly, the Bankura soils, 11A and 12A, show a greater runoff for the 12A soil at a lower slope than that for the 11A soil at a higher slope. It seems, therefore, that the moisture status of the soil previous to a storm may considerably influence the amount of runoff. But whereas this is likely to be apparent for any one soil when erosion occurs in it at different times of the year, this may not be evident when a group of soils are compared with each other. Because the differences, if any, due to the difference in the moisture content of the soils, may be masked by the effects of other factors affecting runoff. This is best illustrated by the runoff per cent again, of 2A, 8A and DF soils which, as mentioned before, are more or less at the same slope. The DF soil with a lower moisture content has given more runoff

TABLE I

Rainfall, runoff and soil losses

Soil No.	Locality	Slope p. c.	Moisture content before rainfall p. c.	Rainfall in inches	Duration of rainfall	Rainfall in inches per hour	Runoff in c.c.	Soil loss in gm.	Runoff per cent	Soil loss in gm. per in. rain	Soil loss in gm. per 1000 c.c. runoff	Clay and Silt (mechanical analysis) p. c.
		a	b	c	d	e	f	g	h	i	j	k
1A	Jyadebpur (Dacca) ...	15.0	14.12	0.81	50 min.	0.97	1692	28.25	39.35	34.87	16.6	50.5
2A		5.0	10.43				1225	12.20	28.49	15.06	9.9	53.2
3A	Agartola (Tippera) ...	16.1	20.71	1.84	1 hr. 40 min.	1.09	4275	151.44	43.79	82.30	35.42	49.3
4A		12.5	25.63				3685	156.90	37.75	85.27	42.57	42.5
5A	Durgapur (Mymensingh) ...	8.2	1.90	0.45	34 min.	0.79	...	...	...	...	...	5.1
6A		4.5	3.70				...	...	...	...	...	8.8
7A	Duars (Jalpaiguri) ...	8.7	33.20	1.32	31 min.	2.56	2835	58.01	40.46	43.94	20.46	42.8
8A		5.0	30.17				2515	32.65	35.89	24.73	12.98	50.9
9A	Sukna (Darjeeling) ...	20.2	23.90	0.25	22 min.	0.67	390	6.02	28.64	24.08	15.43	47.0
10A		4.8	28.50				590	3.12	44.45	12.48	5.29	56.6
11A	Bankura ...	12.9	22.31	0.21	16 min.	0.76	695	10.85	62.31	51.66	15.61	19.7
12A		3.7	36.40				850	6.26	76.26	29.80	7.36	45.6
15A	Bolpur (Birbhum) ...	10.1	3.6	0.45	33 min.	0.81	760	10.98	31.79	24.40	14.44	35.8
16A		11.6	4.1				925	14.72	56.46	32.71	15.91	39.4
DH	Dacca Hall (Dacca) ...	21.3	...	0.63	Occasional, 7 days	...	1020	12.28	30.47	19 50	12.04	49.3
			...	0.25	Do. 5 days	..	300	9.89	21.11	39.56	32.96	49.3
DF	Dacca Farm (Dacca) ...	6.5	6.21	0.86	Do. 5 days	...	2175	39.56	45.48	45.90	18.19	48.5

than either the 2A or the 8A soil, although the precipitation in the case of the 2A or the 8A soil is either equal to, or heavier than that in the case of the DF soil.

From all that has been stated above it appears that the erosion of the soils examined is considerably influenced in addition to the slope and the previous moisture-status by the properties of the soils themselves. It would be interesting, therefore, to study from a comparative point of view the extent to which these properties collectively influence erosion of the soils under more controlled conditions, and also to find out those properties that are more responsible in causing runoff and erosion. These two studies have been taken up in Parts II and III respectively.

Comparison of field and laboratory measurements

In Part II the erosion measurements have been made in the laboratory with soils packed in boxes of the same dimensions as those used in the field measurement. Here the amount, intensity and the duration of rainfall as well as the slope are controlled. The figures thus obtained certainly offer a much better comparison of the erodibility of the soils. However, it would be interesting to see to what extent the laboratory measurement reflects the erosion taking place under field conditions. In Table II the average soil-losses in grams per 1000 c.c. runoff obtained at various slopes by laboratory measurement are compared with those obtained in the field already reported in this part.

TABLE II

Soil losses in field and laboratory measurements

Soil No.	Slope p. c. (Field)	Rainfall in inches (Field)	Soil loss in gm. per 1000 c. c. runoff		Slope p. c. (Laboratory)
			(Field data)	(Laboratory data)	
	v	w	x	y	z
1A 2A	15.0 5.0	0.31	16.6 9.9	27.6 20.2	15.0 5.0
3A 4A	16.1 12.5	1.84	35.4 42.6	28.0 27.0	15.0 12.5
7A 8A	8.7 5.0	1.32	20.5 13.0	18.7 9.8	8.7 5.0
9A 10A	20.2 4.8	0.25	15.4 5.3	45.5 23.1	20.0 5.0
11A 12A	12.9 3.7	0.21	15.6 7.4	23.8 13.5	12.5 5.0
15A 16A	10.1 11.6	0.45	14.4 16.0	21.7 20.0	10.0 10.0
DH	21.3	{0.63 {0.25	12.0 33.0	53.1	20.0
DF	6.5	0.86	18.2	26.3	5.0

The laboratory measurement of erosion has been carried out under 1 in. of rainfall and the soil loss given in column (y) of the above table is obtained from the average soil loss figure of three successive inches of rain at the respective slope. It will be seen from the table that where the amount of rainfall in the field has been more than one inch, for example, 3A and 4A, the soil losses are greater than those obtained in the laboratory. Where the rainfal has been approximately 1 in. as in 7A and 8A, the soil losses are more or less equal to those obtained in the laboratory. And where it has been smaller than one inch, as in most of the remaining cases, the laboratory measurement gives higher values in soil losses. It appears, therefore, that under similar rainfall the results of laboratory and field measurements are also similar. The laboratory measurement can thus be employed with advantage to get an approximate idea of the extent of erosion occurring in the field. The importance of this is obvious. The technique usually employed in measuring the erosion in the field is not only very costly but it also fails to give an absolute measure of the erosion which varies from year to year depending upon the amount, intensity and distribution of annual rainfall. Thus the field measurement can only be approximate and is as defective as the laboratory measurement possibly is. Besides, the field measurement is of limited applicability, since the results for a particular plot will apply for that plot only and will not be applicable to a soil, not far away, due to variation in slope, physical property and other factors. Laboratory measurement, on the other hand, although possessing the same inherent defects as in the field measurement, has a considerable economic advantage over the latter and can be employed with greater success by carrying out the measurement on a large number of soils in the neighbourhood with practically very little additional cost.

The loss of fertility elements. Although the field measurement employed here is of a very preliminary nature, nevertheless, it gives an approximate idea of the possible extent of erosion which these soils are likely to suffer annually when put under cultivation without erosion-control measures. The soil loss in tons per acre per inch rain has been calculated from the figures in column (i) of Table I, and are given in Table III together with the annual precipitation, the run off per cent of column (h) of Table I, the percentage of nitrogen and P_2O_5 in the eroded material, etc.

TABLE III

The annual runoff and loss of soil and fertility elements

Soil No.	Annual precipitation in inches (approx.)	Runoff per cent	Soil-loss in tons per acre per inch rain	Annual runoff in inches	Annual soil-loss in tons per acre	Nutrients in eroded material: Total N p. c.	Nutrients in eroded material: Available P_2O_5 p. c.	Annual loss of nutrients in eroded material per acre in lb.: Total N	Annual loss of nutrients in eroded material per acre in lb.: Available P_2O_5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1A	68	39·4	0·69	26·8	47·0	0·15	0·004	157·5	4·2
2A		28·5	0·30	19·4	20·4	0.27	0·005	123·4	2·3
3A	72	43·8	1·64	31·5	116·6	0.38	0·006	992·5	15·7
4A		37·8	1·71	27·2	123·1	0·29	0·006	799·7	16·5
7A	196	40·5	0·87	79·3	170·5	0·81	0·007	3093·6	26·7
8A		35·9	0·49	70·3	96·0	0·84	0·008	1806·3	17·2
9A	150	28·6	0·48	43·0	72·0	0·99	0·007	1596·7	11·3
10A		44·5	0·25	66·7	37·5	0·87	0·006	730·8	5·04
11A	55	62·3	1·03	34·3	56·7	0·32	0·005	406·4	6·4
12A		76·3	0·59	42·0	32·5	0·29	0·005	211·1	3 6
15A	57	31·8	0·48	18·1	27·4	0·12	0·004	73·7	2·5
16A		56·5	0·65	52·2	37·1	0·25	0·005	207·8	4·2
DH	70	30·5	0·39	21·3	27·3				
		21·1	0·79	14·8	55·3				
DF	70	45·5	0·91	31·8	63·7	0·75	0·005	1070·2	7·3

It will be seen from Table III that the annual precipitation in the areas examined varies from 55 to 200 in. (column 2). All of this rain will not cause erosion but the bulk of it will. If, however, we assume that the whole of the rain will be effective in the same way as the observed shower in the field measurement, the probable annual runoff may be as much as 14.8—79.3 inches (column 5) and the annual soil loss as much as 20—170 tons per acre (column 6). This soil loss certainly occurs from the top, the most fertile portion of the soil. The magnitude of this loss and its consequent effect on crop growth may be further reailzed from the annual loss of total nitrogen and available P_2O_5 in the eroded material which may be as much as 74—3094 lb. and 2.3—26.7 lb. per acre respectively (columns 9 and 10).

Summary

1. In order to gain some information of the relative erodibilities of Bengal soils field measurement of erosion has been made in small bare plots under short storms at eight different places distributed over Bengal, where erosion in the cultivated fields does occur. Two soils at each place have been examined.

2. All the soils investigated are found to be fairly erosive. As much as 21—76 per cent of the precipitation may escape as runoff and as much as 20—170 tons of soils may be eroded annually carrying with it 74—3094 lb. of total nitrogen and 2.3—26.7 lb. of available P_2O_5 approximately.

3. The moisture-status of a soil previous to a storm considerably influences the runoff.

4. The soils at more or less the same slope are found to erode very differently, one eroding 1½ to 3 times as much as others. Furthermore, a soil at a lower slope is found to erode more than an adjacent soil at a higher slope.

5. Therefore, it is proposed to study further the relative erodibilities under more controlled conditions in the laboratory. The merits of the laboratory and field measurements are also discussed.

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PLANT-FOOD REQUIREMENTS OF CALCAREOUS SOILS

I. OPTIMUM REQUIREMENTS OF PHOSPHORUS FOR PUSA CALCAREOUS SOILS

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(With two text-figures)

Since the beginning of agricultural research, the problem of determining plant-food requirements of a soil has been of major importance. Various methods of solving this problem have been proposed, including a complete analysis of the soil, extraction by acids of various kinds and strengths as well as by physiological means. It must be admitted, however, that at the present time there is no known method which is both accurate and universally applicable.

The fact that the proposed methods are all empirical in character is a great draw-back, but the serious objection is that the results give a measure of the condition of a soil at a particular time only and obviously cannot apply to its condition at different times throughout the year. There is probably no hard-and-fast line between the 'non-available' and the 'available' constituents, the one set gradually merging into the other.

The whole question of available plant food is necessarily bound up with the complex relationship that exists between plant and soil, and it is unlikely that any simple or single method will be devised to overcome the inherent difficulties attaching to the problem and be generally applicable to different sets of conditions. The admitted lack of agreement obtained with the various methods at present in use is undoubtedly due, to a large extent, to the variety of factors involved as well as to the fundamental objections which may be raised to any one method. We are still very ignorant of the process of assimilation by the growing plant, and until we have more information on this subject, methods of estimating available plant food in soils must continue to be largely empirical and the results merely first approximations.

The belief of the practical agriculturist that the chemist can give reliable advice purely as a result of analysis of his soil, dies hard ; it is still a common experience to receive a sample of a few ounces of soil with a request for detailed recommendations as to the manuring of the land in question. Now-a-days no agricultural chemist of repute would be so bold as to make such recommendations merely on the basis of a soil analysis. He knows that plant food supply is only one of the many factors which may exert a dominant influence on crop production. Detailed knowledge of climate, drainage, method of cropping, and so forth, must be available. Given such information, soil analysis can be of great value, but the final test must always consist of actual manurial trials on the land. For the plant must be accepted as the ultimate criterion and all conclusions drawn according to plant response.

It is well known that the growing plant itself possesses power to a greater or less degree to feed directly on phosphates and that some plants possess specially marked powers [Truog, 1916]. As a result, no common limiting value for available phosphoric acid can be suggested, as given by Dyer [1894], which will be equally applicable for all types of soil. Consequently, this value must be worked out for different soils. Even in the same soil it will be different according to the types of crop grown on it from time to time, as crops vary greatly in feeding power and phosphate requirement. There is, therefore, a need for studying these two properties for various crops.

The problem becomes further complicated by the fact that different types of soil

require different systems of manuring. Although calcareous soils round about Pusa belonging to the Indo-Gangetic alluvium and containing 30 to 40 per cent of chalk, yield extremely low values of available phosphoric acid when measured by the ordinary laboratory methods, the action of phosphatic fertilizers on them in actual farm practice is extremely erratic. As for instance, the application of superphosphate alone, more often than not, yields disappointing results, and the best results are usually obtained when applied in conjunction with heavy organic manures.

Earlier work of this laboratory lays stress on the following three factors for this uncertain action of superphosphate in calcareous soils, viz.:

1. The retention of soluble phosphoric acid of superphosphate in the surface layers as insoluble calcium phosphates by chemical combination with the large amount of calcium carbonate normally present in these soils and the consequent localized action of superphosphate as shown by Harrison and Das [1921];

2. the depressing action on the cropping power of calcareous soils of gypsum which is present to the extent of 50 to 60 per cent in commercial superphosphate as shown by the author [Das, 1933]; and

3. the deleterious effect of the surface application on the availability of superphosphate in calcareous soils as recently demonstrated by the author [Das, 1945].

The depressing effect of the factors (1) ond (3) can be successfully counteracted by applying superphosphate 4 to 6 inches deep, which has been shown by the author [Das, 1945] to bring about the maximum crop production in calcareous soils.

As laboratory methods alone fell far short of expectations in finding optimum plant food requirements of soils, it was considered desirable to discover the same by actual manurial trials on the land.

Experimental

Two series of pot experiments were instituted in 1933 with a calcareous Pusa soil containing 33 per cent of calcium carbonate. Four pots of similar dimensions, viz. 9 in. in diameter and 12 in. high formed a group and received similar treatment. In one series nitrogen and potash were added as a basal dressing to all the pots at the rate of 60 lb. per acre as sulphate of ammonium and potassium chloride respectively. P_2O_5 as precipitated calcium phosphate was added to different groups of pots at the rate of 25, 50, 75, 100, 200 and 400 lb. per acre, which correspond respectively to 0.00125, 0.0025, 0.00375, 0.005, 0.01, and 0.02 gm. P_2O_5 per 100 gm. of soil. In the other series nitrogen was supplied as a basal dressing to all the pots at the same rate as in the first series in the form of dried leaves of sunn-hemp (*Crotalaria juncea*). The dried green manure added contained potash equivalent to 80 lb. per acre and P_2O_5 equivalent to 25 lb. per acre. Allowance was made for the latter while adding increasing amounts of precipitated calcium phosphate to supply P_2O_5 to different groups of pots as in the first series. Each pot contained 15 kilos of air-dry soil. The pots were watered from the top and 16 per cent of moisture was maintained in the soil throughout the expriment. The maximum water-holding capacity of the soil was 48 per cent. There was a group of control pots in each series for comparison where no phosphate was added, but nitrogen and potash were supplied as a basal dressing. *Ragi* (*Eleusine coracana*) was sown on 16 June and the crop harvested on 10 October 1933. Although the weights of both grain and straw per pot were recorded separately, only the mean yields of grain are given in Table I along with their statistical examination by Fisher's [1932] analysis of variance.

TABLE I

The mean yields of ragi (Eleusine coracana) *grain in Pusa calcareous soil with increasing doses of calcium phosphate*

P_2O_5 per acre in lb.	A Series with N as $(NH_4)_2SO_4$		B Series with N as dried sunn-hemp leaves	
	Mean yield in gm.	Percentage of increase over control	Mean yield in gm.	Percentage of increase over control
Control	11.60	—	11.88	—
25	19.33	66.4	16.10	35.3
50	20.18	74.1	20.23	70.0
75	25.95	123.7	26.20	120.2
100	26.88	140.5	27.80	133.6
200	23.98	106.8	25.63	115.7
400	28.38	144.7	26.95	126.9
Standard error for comparison of mean yields ...	1.33		2.03	
Critical difference for 1 per cent ...	3.77		5.75	
Critical difference for 5 per cent ...	2.77		4.22	

From Table I it is evident that the differences in mean yields of *ragi* grain between the control and every other treatment in both the series are highly significant, being greater than the critical value of difference even for one per cent level of significance. Similar differences of other treatments over either 25 or 50 lb. P_2O_5 per acre are also highly significant, but among 25 and 50 lb. of P_2O_5 themselves, or among the remaining treatments no significance in mean yields of grain is found. The application of 75 lb. of P_2O_5 per acre yields practically the maximum crop production, although higher applications of P_2O_5 appear to give slightly better crop returns which are not, however, significant at all. Consequently, the application of 75 lb. of P_2O_5 per acre meets the optimum phosphate requirements of calcareous soils here for a *kharif* (summer) crop like *ragi*.

Another striking fact noticed is that green manure applied to soils in the dry state as in the present instance does not prove better than ammonium sulphate, when applied to supply nitrogen. This may be attributed to the fact that most of the advantages accruing from the process of fermentation of green plant materials are lost, while using the same in a dried form.

Next it was considered desirable to discover any relationship that might exist between the available phosphoric acid determined by ordinary laboratory methods of the soils treated with increasing doses of the phosphatic fertilizer and the corresponding crop yields. For this purpose soil samples from the differently treated pots of both A and B series of experiments were examined for available phosphoric acid by Dyer's [1894] citric acid method as well as by the potassium carbonate method of the author [Das, 1926]. The results obtained are set forth in Table II along with the mean yields of *ragi* reproduced from Table I for comparison.

TABLE II

Available phosphate of soil samples of pots treated with increasing doses of phosphatic fertilizer and the corresponding crop yields

P_2O_5 added per acre in lb.	Control	25	50	75	100	200	400
P_2O_5 added per 100 gm. of soil in gm.	*nil*	0.00125	0.0025	0.00375	0.005	0.01	0.02
A Series. With N as ammonium sulphate							
Percentage of P_2O_5 by K_2CO_3	0.0028	0.0037	0.0053	0.0056	0.0059	0.0092	0.0157
Percentage of P_2O_5 by citric acid	0.0009	0.0009	0.0009	0.0010	0.0011	0.0019	0.0029
Mean yield of *ragi* in gm.	11.60	19.33	20.18	25.95	26.88	823.98	28 .3
B Series. With N as dried sunn-hemp							
Percentage of P_2O_5 by K_2CO_3	0.0032	0.0035	0.0039	0.0046	0.0051	0.0086	0.0161
Percentage of P_2O_5 by citric acid	0.0009	0.0011	0.0014	0.0015	0.0016	0.0018	0.0041
Mean yield of *ragi* in gm.	11.88	16.10	20.23	26.20	27.80	25.63	26.95

The above results are graphically represented in Figs. 1 and 2.

It is evident that the values of available phosphoric acid by the citric acid method are extremely low up to the application of 100 lb. of P_2O_5 per acre in both the series of experiments. Besides, they offer such great manipulative difficulties in their estimation as to render their accuracy hardly reliable. On the other hand, the potassium carbonate method gives values of available phosphoric acid which show a fair increase with gradually higher applications of P_2O_5 and are significantly related to the corresponding crop yields up to the limit of 75 lb. of P_2O_5 per acre. Taking the average of both the series which are similar experimental conditions, it is noticed that 0.005 per cent of available phosphoric acid meets the optimum phosphate requirements of calcareous soils and produces the maximum crop yield Although higher applications of P_2O_5 per acre undoubtedly increase considerably the values of available phosphate either by the citric acid or the potassium carbonate method, a correspondingly high increase in crop yields is not secured. Higher values of available phosphate may be attributed to the effect of mass action only.

Therefore, it may be concluded that the value of 0.005 per cent of available phosphoric acid as determined by the potassium carbonate method resulting from the application of 75 lb. of P_2O_5 per acre meets the optimum phosphate requirements of the Pusa calcareous soils for maximum crop production.

In order to obtain further confirmation pot experiments were repeated in 1933 and 1934 with mustard and oats respectively. Pots and other working details were the same as in the case of the previous pot experiments with *ragi*.

Mustard was sown on 11 November, 1933 and the crop harvested on 9 March, 1934. Oats were sown on 3 November, 1934 and the crop was harvested on 19 March, 1935. The mean yields of mustard and oats are given in Table III.

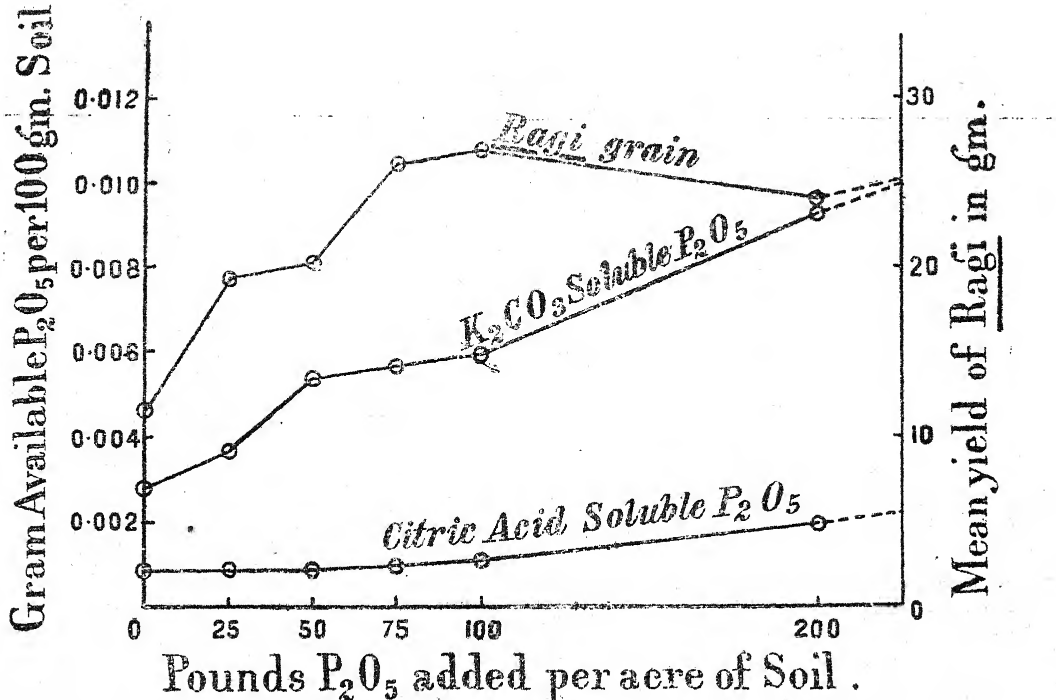

FIG. 1. A Series

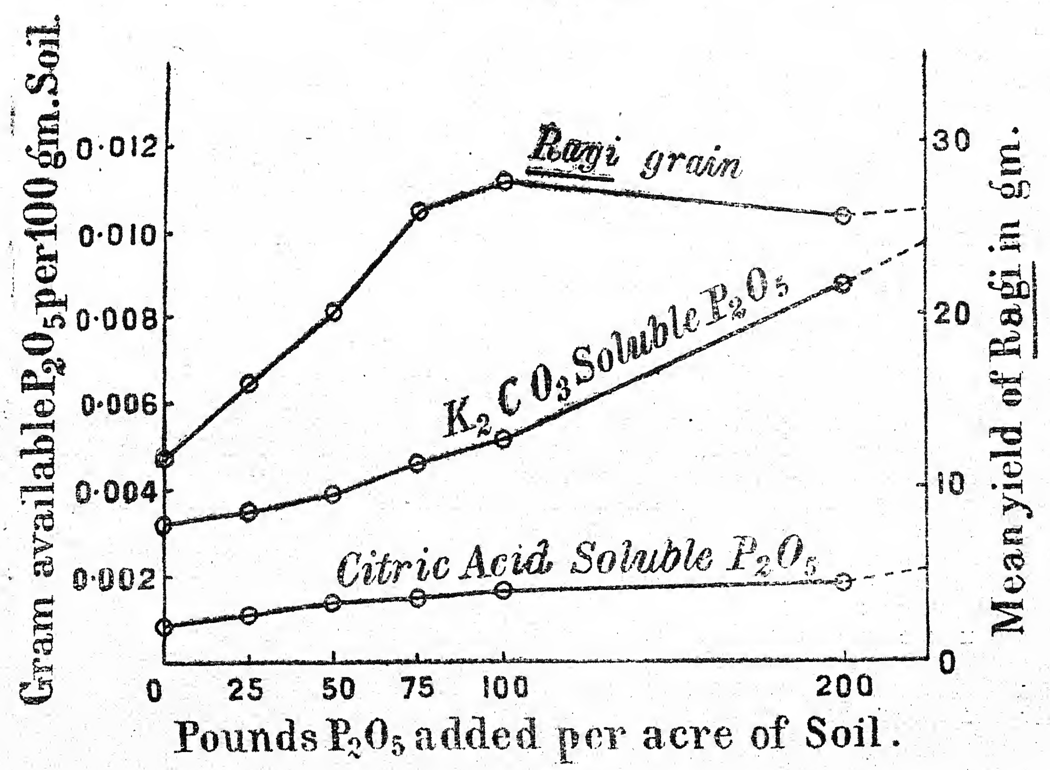

FIG. 2. B Series

FIGS. 1 and 2. The graphical representations for the comparison of the available phosphate of soils under increasing doses of the phosphatic fertilizer with the corresponding crop yields of A and B series of pot experiments respectively

TABLE III

Mean yields of mustard and oats grain in Pusa calcareous soil with increasing doses of calcium phosphate

	Mustard 1933-34			Oats 1934-35	
P_2O_5 per acre in lb.	Mean yield in gm.	Percentage of increase over control	P_2O_5 per acre in lb.	Mean yield in gm.	Percentage of increase over control
Control	6.05	—	Control	30.10	—
60	10.45	72.7	50	107.00	255.5
70	10.93	80.7	60	120.43	300.1
80	13.40	121.4	70	113.90	278.4
90	12.18	101.3	80	112.53	273.8
100	9.85	62.8	100	115.60	284.0
Standard error for comparison of mean yields ...	1.255			4.83	
Critical difference					
For 1 per cent	3.61			13.90	
For 5 per cent	2.64			10.15	

From Table III it is evident that the application of 80 and 60 lb. of P_2O_5 per acre gives the maximum yields of mustard and oats respectively, and meets the optimum phosphate requirements of calcareous soils for these crops.

Therefore, the four series of pot experiments detailed above indicate that the application of 60, 75 and 80 lb. of P_2O_5 per acre meets the optimum phosphate requirements of calcareous soils for oats, *ragi* and mustard respectively.

In order further to test these conclusions arrived at from pot experiments, field trials in the Punjab Experimental Area of the Pusa Farm were undertaken in 1934 in three adjacent $\frac{1}{4}$ acre plots, each of which was subdivided into 18 equal sub-plots of $\frac{1}{72}$ acre each measuring about 30 ft. north to south and 20 ft. east to west. A basal dressing of potash and nitrogen at the rate of 60 lb. per acre as potassium chloride and ammonium sulphate respectively was given to all the sub-plots and phosphate as superphosphate applied 4 inches below the surface soil by deep ploughing to the plots concerned. There were six treatments of nine replications each.

The treatments were P_0, P_1, P_2, P_3, P_4 and P_5 representing respectively control with nitrogen and potash only but no phosphate, and 50, 70, 80, 90 and 100 lb. of P_2O_5 per acre besides the basal dressings of nitrogen and potash as in the control plots.

Ragi seedlings grown outside and about three weeks old were transplanted on 11 July 1934 in 31 lines one foot apart with 39 plants in each placed six inches apart. A fortnight after transplanting, *ragi* seedlings were dying at places ; these were replaced by fresh ones grown outside. Plants progressed well and during harvest one line from the surrounding border of each sub-plot was rejected, thus leaving 29 lines with 37 plants in each. On 9 September *ragi* plants from the border were cut off and rejected, and ripe cobs collected on 11 and 22 September, 1934. This interval was given on account of unequal ripening.

Next a crop of oats was raised in these very plots in the following winter of 1934 in order to study the residual effect of the fertilizers. Oats were sown on 3 November 1934, and the crop was harvested on 23 March 1935. Mean yields of *ragi* and oats grain are given in Table IV.

TABLE IV

Mean yields of ragi *and oat grain in field experiments with Pusa calcareous soil under increasing doses of a phosphatic fertilizer*

P_2O_5 per acre in lb.	Primary effect		Residual effect	
	Ragi 1934		Oats 1934-35	
	Mean yield in lb.	Percentage of increase over control	Mean yield in lb.	Percentage of increase over control
P_0=Control ...	22.76	—	8.77	—
P_1= 50 ...	25.04	10.0	9.09	3.7
P_2= 70 ..	25.84	13.2	9.26	5.6
P_3= 80 ...	25.87	13.7	9.43	7.5
P_4= 90 ...	26.21	15.2	10.38	18.4
P_5=100 ...	25.37	11.5	8.98	2.4
Standard error for comparison of mean yields ...		1.00		0.607
Critical difference				
For 1 per cent ...		2.69		1.64
For 5 per cent ...		2.02		1.22

From Table IV it is evident that the differences in mean yields of *ragi* grain between the control and every other treatment are significant, being greater than the critical value of difference for 1 per cent level of significance in all cases except 50 and 100 lb. of P_2O_5 per acre where 5 per cent level of significance holds. Thus, of the treatments showing 1 per cent level of significance, the application of 70 lb. of P_2O_5 per acre produces the maximum crop yield from the farmer's point of view, although 80 and 90 lb. of P_2O_5 give slightly better returns which were not, however, significant at all. With regard to the oat crop no phosphatic treatment has any residual effect except the original treatment of 90 lb. of P_2O_5 per acre.

It will thus be evident that the application of 70 lb. of P_2O_5 per acre on a field scale can satisfactorily meet the optimum phosphate requirements of calcareous soils for a *kharif* crop like *ragi*. It is interesting to note that this limit is not very different from the optimum dose of 75 lb. of P_2O_5 found in the case of pot experiments.

Next it was thought worthwhile to get an idea of the practical value of the manurial requirements of these soils, as the farmer would like to know what return he could expect from manuring these soils. For this purpose, the economics of the manurial treatment may be taken into account. From the cropping experiments detailed above it was found on calculation that by spending about Rs. 8 to 10 extra as the cost of adding per acre about 80 to 100 lb. of P_2O_5 as superphosphate according to the optimum phosphate requirements of various crops in these calcareous soils, enough extra yields of *ragi*, mustard, and oats over the control were obtained which justified the manurial treatment by leaving a decent margin of profit. The residual effect of 60 lb. of P_2O_5 was, however, found not to be economically significant.

It was then of interest to know the rate of assimilation of important food materials by the growing crop from the fertilizers applied. For this purpose, the representative samples of *ragi* grain collected from the nine replicated sub-plots of each treatment were submitted to chemical analysis and the results obtained are given in Table V.

TABLE V

The chemical composition of ragi *grain grown in field experiments with Pusa calcareous soil under increasing doses of a phosphatic fertilizer*

P_2O_5 per acre in lb.	Per cent constituents calculated on dry *ragi* grain					Mean yield of grain in lb. per plot
	Ash	Sand	K_2O	N	P_2O_5	
P_0 = Control ...	3.32	0.16	0.861	1.53	0.498	22.76
P_1 = 50 ...	3.21	0.21	0.792	1.56	0.506	25.04
P_2 = 70 ...	3.15	0.16	0.802	1.50	0.543	25.84
P_3 = 80 ...	3.09	0.21	0.819	1.42	0.600	25.87
P_4 = 90 ...	2.96	0.14	0.724	1.47	0.642	26.21
P_5 = 100 ...	3.09	0.14	0.809	1.46	0.609	25.37

It is seen that the P_2O_5 content of the *ragi* grain increases appreciably with the increased applications of the phosphatic fertilizer, while the nitrogen content tends to decrease slightly. Its potash content, however, does not exhibit any appreciable variation.

SUMMARY

1. Pot and field experiments substantially confirm the conclusion that the application of 60, 70 and 80 lb. of P_2O_5 per acre with basal dressings of nitrogen and potash yields the maximum crop of oats, *ragi*, and mustard respectively in Pusa calcareous soils and meets the optimum requirements of these soils for the above crops.

The cropping results were both statistically and economically tested and found to be highly significant.

2. The examination of the available phosphate of the soil samples showed that the values obtained with the author's potassium carbonate method were significantly related to the crop yields of *ragi* up to the limit of 75 lb. of P_2O_5 per acre. Hence, 0.005 per cent of available phosphoric acid of a calcareous soil resulting from the application of 75 lb. of P_2O_5 per acre corresponds to the maximum crop production.

3. On the other hand, the values of available phosphate obtained with the Dyer's citric acid method did not yeild such significant results as above and failed to corroborate the results of the crop yields.

4. The examination of the rate of assimilation of important food materials by the growing crop from the soil and the applied fertilizers showed that the P_2O_5 content of the *ragi* grain increases appreciably with the increased applications of the phosphatic fertilizer, while the nitrogen content tends to decrease slightly. Its potash content, however, does not show any appreciable variation.

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PLANT-FOOD REQUIREMENTS OF CALCAREOUS SOILS

II. OPTIMUM REQUIREMENTS OF NITROGEN FOR PUSA CALCAREOUS SOILS

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(With Plate XXI)

Nitrogen is by far the most important of the principal plant-food materials in which Indian soils are usually deficient. The manurial problem is, therefore, in the main, one of nitrogen deficiency in India. Calcareous soils in the Indo-Gangetic alluvium in Bihar respond well to all types of nitrogenous fertilizers. Oil cakes are available in plenty in this part of the country where the practice of green manuring is also well-known. Further, artificial fertilizers like ammonium sulphate, sodium nitrate, ammonium phosphate, etc. are gradually finding greater application in agricultural practice here. Information on the optimum requirements of nitrogen for proper crop production in these soils is however lacking. As oil cakes are easily available nitrogenous manures commonly used in farm practice here, their action for the supply of nitrogen to these calcareous soils was first studied.

Experimental

A sample of apricot seed cake on which some experiments were carried out in this laboratory by the author [Das, 1945] to find its use as a nitrogenous manure, was selected for the present inquiry. Biochemical studies demonstrated that 63 per cent of nitrogen contained in the cake could be transformed into available forms in Pusa calcareous soils in eight weeks and that further incubation did not increase the available nitrogen in the soil mixture. Next it became of interest to determine how much of the cake would meet the optimum requirements of nitrogen for maximum crop production in these calcareous soils. As the cake with 6.7 per cent of nitrogen contains also 1.49 per cent of P_2O_5 and 1.09 per cent of potash, extra doses of these two constituents were not applied as fertilizers in the following pot experiments.

A series of pot experiments was started in the winter of 1932 with the Pusa calcareous soil containing about 35 per cent of calcium carbonate. Wheat was chosen as the *rabi* (winter) crop which responds readily to nitrogenous manures. Four pots of similar dimensions, viz. 9 in. diameter by 12 in. high formed a group and received similar treatment. The pots contained 15 kilos of air-dry soil in each and 16 per cent of moisture was maintained in the soil throughout the experiment. There was a group of control pots where no cake was applied. After the wheat crop was harvested, a second crop of *ragi* (*Eleusine coracana*) was raised in the following summer of 1933 in these pots without any further manurial treatment in order to determine the residual effect of the cake. The cake was applied to the pots according to the scheme shown in Table I.

TABLE I

The scheme of the application of the oil cake to pot culture experiments

Pot numbers	Nitrogen from the cake per kilo of soil in mg.	Manurial constituents per acre of soil from the cake in lb.		
		N (Based on 63 per cent availability)	P_2O_5	K_2O
1 to 4	Control	—	—	—
5 to 8	10	12.6	4.47	3.27
9 to 12	20	25.2	8.94	6.54
13 to 16	40	50.4	17.88	13.08
17 to 20	50	63.0	22.35	16.35

Wheat seeds were sown on 10 November, 1932 and the crop was harvested on 20 March, 1933. After the harvest of wheat-crop was over, *ragi* seeds were sown in these very pots in the next season on 11 June, 1933 to study the residual effect of the cake. The *ragi* crop was harvested on 3 October, 1933. Mean yields of grain of both the crops are given in Table II along with their statistical examination by Fisher's [1932] analysis of variance.

TABLE II

The primary and the residual effect of apricot seed cake on the yields of wheat and ragi *respectively in Pusa calcareous soil*

Nitrogen per acre of soil in lb.	Primary effect with wheat		Residual effect with *ragi*	
	Mean yield in gm.	Percentage of increase over control	Mean yield in gm.	Percentage of increase over control
Control	4.34	—	9.08	—
20	8.01	84.6	10.63	17.1
40	8.26	90.4	10.13	11.6
80	10.08	132.3	10.55	16.2
100	11.06	155.0	12.20	34.4
Standard error for comparison of mean yields	0.59		0.98	
Critical difference				
For 1 per cent	1.74		2.89	
For 5 per cent	1.26		2.09	

It is seen that the increase in the yield of wheat over the control is high according to the increasing doses of the manure applied and that the differences in mean yields of grain between the control and every other treatment are highly significant being greater than the critical value of difference for 1 per cent level of significance. The maximum crop was practically obtained by the application of 80 lb. of nitrogen per acre as cake, although a little better crop was produced by 100 lb. of nitrogen per acre which was not however significant.

In the case of *ragi*, although the increase in the yield of grain over the control indicated the residual effect of every treatment of the cake, 100 lb. of nitrogen only gave significantly higher yield than the control. It may therefore be concluded that the residual effect of the cake can persist till the next succeeding crop in calcareous soils, only when it is initially applied to the land at the rate of 100 lb. of nitrogen per acre.

Next, cropping experiments both in pots and fields were instituted in the winter of 1934 to see how much of an artificial nitrogenous fertilizer like ammonium sulphate was needed to meet the optimum requirements of nitrogen for proper crop production in calcareous soils.

Similar pots as in the case of pot experiments with cake were used and similar procedure was followed. Basal dressings of potash and phosphoric acid at the rate of 80 lb. and 100 lb. per acre as potassium chloride and superphosphate respectively were given to all the pots. There was a group of control pots for comparison, where potash and phosphate were added but no ammonium sulphate. Wheat seeds were sown on 28 October, 1934 and the crop was harvested on 14 March, 1935. Mean yields of grain are presented in Table III along with their statistical examination by Fisher's [1932] analysis of variance.

TABLE III

Mean yields of wheat in Pusa calcareous soil under increasing doses of ammonium sulphate

Nitrogen per acre of soil in lb.	Mean yield in gm.	Percentage of increase over control
Control ...	25.20	—
40 ...	32.40	28.6
60 ...	36.05	43.1
70 ...	36.18	43.7
80 ...	31.53	25.1
100 ...	27.20	8.0

Standard error for comparison of mean yields ...	1.557
Critical difference	
For 1 per cent ...	4.48
For 5 per cent ...	3.27

It is seen that the increase in the yield of grain is high over the control with every treatment of ammonium sulphate except 100 lb. of nitrogen per acre and that the differences in mean yields of grain between the control and every other treatment except 100 lb. of nitrogen per acre are highly significant being greater than the critical value of difference even for 1 per cent level of significance. The maximum crop was practically obtained by the application of 60 lb. of nitrogen per acre. Therefore it may be concluded that the application of 60 lb. of nitrogen per acre as ammonium sulphate meets the optimum requirements of nitrogen for the maximum production of a crop like wheat in calcareous soils.

The cropping results of the previous set of pot experiments showed that the application of 80 lb. of nitrogen per acre as cake met the nitrogen requirements of these soils for wheat.

In order, therefore, to test these conclusions arrived at from pot experiments, field experiments were conducted in the Punjab Experimental Area of the Pusa Farm in the winter of 1934 in two ½ adjacent acre plots. Each of these plots was sub-divided into 18 equal sub-

plots of $\frac{1}{73}$ acre each measuring about 30 ft. north to south and 20 ft. east to west. A basal dressing of potash and phosphoric acid at the rate of 80 and 100 lb. per acre as potassium chloride and superphosphate respectively was given to all the sub-plots, and nitrogen as ammonium sulphate to the plots concerned. There were six treatments of six replications each.

The treatments were N_0, N_1, N_2, N_3, N_4 and N_5 representing respectively control with potash and phosphoric acid only but no nitrogen, and 40, 60, 70, 80 and 100 lb. of nitrogen per acre besides the basal dressings of potash and phosphoric acid as in the control plots.

Wheat seeds were sown on 30 October 1924 by means of a drill in 31 lines north to south, 9 in. apart, in each sub-plot. Rejecting one row of plants from all sides of each sub-plot in order to eliminate the border-effect, the wheat crop was harvested on 24 March 1935. In the interval, however, on 25 January 1935, five plants of each sub-plot were collected and 20 such plants from six sub-plots of each treatment photographed, after which their fresh weight was recorded, as given in Table IV.

TABLE IV

Fresh weight of wheat plants about 12 weeks old grown under increasing doses of ammonium sulphate in Pusa calcareous soil

Treatment per acre of soil	Weight of 30 wheat plants in gm.	Percentage of increase over control
N_0=Control, P and K only ...	380	—
N_1= 40 lb. of nitrogen ...	690	81.6
N_2= 60 ,, ,, ...	780	105.3
N_3= 70 ,, ,, ...	820	115.8
N_4= 80 ,, ,, ...	890	134.2
N_5=100 ,, ,, ...	1270	234.2

It is seen that the vegetative growth of wheat plants increases generally with increasing doses of nitrogenous manure. This can be visualized in Plate XXI, where the photograph of the corresponding wheat plants is given.

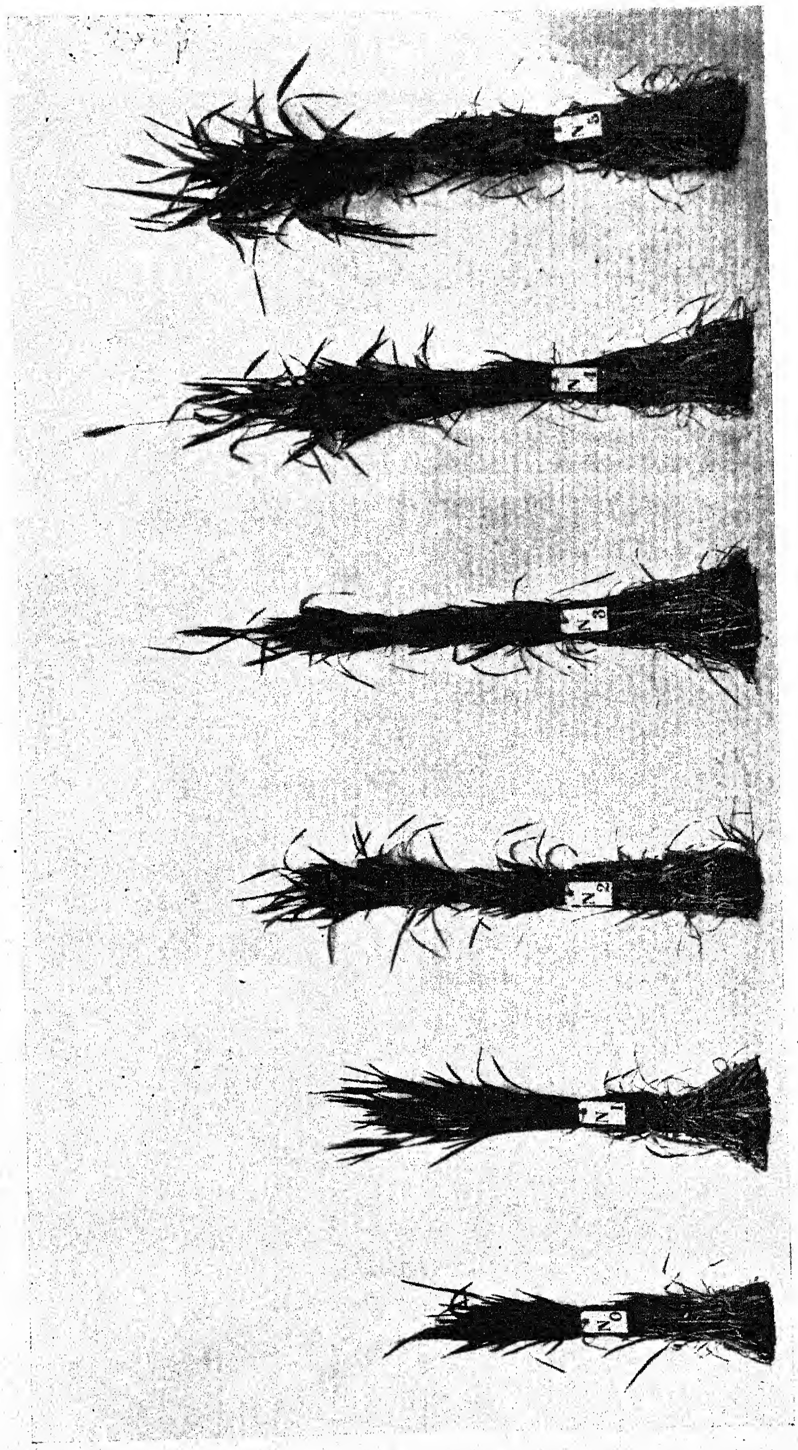
The mean yields of wheat grain with their statistical examination by Fisher's [1932] analysis of variance are set out in Table V.

TABLE V

Mean yields of wheat grain in field experiments with Pusa calcareous soil under increasing doses of ammonium sulphate

Treatment per acre of soil	Wheat 1934-35	
	Mean yield in lb.	Percentage of increase over control
N_0= Control, P and K only ...	13.25	—
N_1= 40 lb. of nitrogen ...	19.10	44.1
N_2= 60 ,, ,, ...	19.55	47.6
N_3= 70 ,, ,, ...	19.85	49.8
N_4= 80 ,, ,, ...	20.52	54.8
N_5=100 ,, ,, ...	21.20	60.0

Standard error for comparison of mean yields ...	1.68
Critical difference for 1 per cent ...	4.78
,, ,, ,, 5 per cent ...	3.50



Wheat plants growing under increasing doses of ammonium sulphate in Pusa calcareous soils

It is seen that the increase in the yield of wheat grain over the control varies between 44 and 60 per cent with increasing doses of ammonium sulphate and that the differences in mean yields of grain between the control and every other treatment are highly significant, being greater than the critical value of difference even for 1 per cent level of significance. Thus, of all the treatments, the application of 40 lb. of nitrogen per acre as ammonium sulphate meets the optimum requirements of nitrogen of these calcareous soils for the maximum production of a crop like wheat. The higher doses produce, no doubt, slightly better yields, which are not however significant. The cropping of the two sets of pot experiments showed that the application of 50 to 60 lb. of nitrogen per acre met the optimum requirements of nitrogen for these soils.

The economics of the manurial treatment shows that in *pot experiments* (1) 9 md. of apricot seed cake costing Rs. 13.8 per acre gave an extra yield of 15.2 md. of wheat over the control, (2) 11.5 md. of cake costing Rs. 17-4 per acre an extra yield of 8.3 md. of *ragi* as the residual effect, (3) 3.5 md. of ammonium sulphate costing Rs. 20-4 per acre an extra yield of 28.7 md. of wheat, and (4) in *field experiments*, 2.3 md. of ammonium sulphate costing about Rs. 13 per acre gave an extra yield of 5 md. of wheat over the control. Except the residual effect of the cake with *ragi*, all the other nitrogenous treatments gave economically significant yields which would justify the manurial treatment leaving a decent margin of profit to the cultivator.

Next it was considered worthwhile to see how the wheat grown under increasing doses of a nitrogenous fertilizer with basal dressings of potassic and phosphatic fertilizers absorbed important food materials. For this purpose, the representative samples of wheat grain collected from the six replicated sub-plots of each treatment were submitted to chemical analysis. The results obtained are given in Table VI.

TABLE VI

The chemical composition of wheat grain grown in field experiments with Pusa calcareous soil under increasing doses of ammonium sulphate

Nitrogen per acre of soil in lb.	Per cent constituents calculated on dry wheat grain					Mean yield of wheat grain in lb. per plot
	Ash	Sand	P_2O_5	K_2O	N	
N_0=Control ...	2.02	0.11	0.770	0.446	2.160	13.25
N_1= 40 ...	1.98	0.14	0.716	0.407	2.321	19.10
N_2= 60 ...	1 90	0.12	0.692	0.421	2.415	19.55
N_3= 70 ...	2.34	0.10	0.616	0.419	2.500	19.85
N_4= 80 ...	2.24	0.08	0.656	0.429	2.503	20.52
N_5=100 ...	2.22	0.15	0.626	0.397	2.547	21.20

It is seen that the nitrogen content of the wheat grain shows a marked increase with the increasing doses of nitrogenous fertilizer applied and the reverse is the case with P_2O_5 content. This result has an important bearing in showing the dangers of nitrogen fertilization from the point of view of plant nutrition. Potash content does not however exhibit any appreciable variation. It was found while growing *ragi* in field experiments detailed in Part I that its P_2O_5 content increased with the increasing doses of a phosphatic fertilizer and the reverse was the case with regard to its nitrogen content.

SUMMARY

1. Two series of pot experiments were started in Pusa calcareous soil with basal dressings of potash and phosphoric acid. In one of them increasing doses of

nitrogen was supplied as oil cake and in the other as ammonium sulphate. In the former series two crops were raised, viz. wheat and *ragi* (*Eleusine coracana*), the latter crop showing the residual effect of the manures. The cropping results showed that the application of 80 lb. of nitrogen per acre as cake met the optimum requirements of nitrogen of these calcareous soils for wheat, and that the residual effect of only 100 lb. of nitrogen per acre persisted till the succeeding crop of *ragi*.

In the latter series only a crop of wheat was raised which showed that the application of 60 lb. of nitrogen per acre as ammonium sulphate met the optimum requirements of nitrogen of these calcareous soils.

2. A similar series of field experiments with ammonium sulphate in Pusa calcareous soils showed that the application of 40 lb. of nitrogen per acre gave the maximum yield of wheat and thus met the optimum requirements of nitrogen for wheat in these soils.

3. All the cropping results for maximum production in both pot and field experiments were statistically and economically tested and found to be highly significant.

4. An examination of the mechanism of absorption of important food materials by the growing crop of wheat from the soil and the applied fertilizers indicated that the nitrogen content of the wheat grain showed a marked increase with the increasing doses of the nitrogenous fertilizer and the reverse was the case with P_2O_5 content. The result has an important bearing in showing the dangers of nitrogen fertilization from the point of view of plant nutrition. The potash content however did not exhibit any appreciable variation.

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COMPARATIVE STUDIES ON INDIAN SOILS

III. BASE EXCHANGE PROPERTIES

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Part I of the series dealt with the basis of the proposed climatic and colour divisions of Indian soils and Part II with the chemical composition of the soils and its variation in the individual profiles due to different climatic conditions under which the soils had been formed The present paper deals with the base exchange properties of the soils including measurements of the total exchange capacity, individual exchangeable bases, and pH. These important soil properties vary in the different climatic zones and also in a given profile. It is proposed to study these variations in the light of the composition of the clay and on the basis of the climatic effects. The soils were classified on climatic and colour bases as follows :

Arid	...	From Mirpurkhas, Mianwali, Lyallpur, Haripur-Hazara.
Semi-Arid	...	From Lahore, Gurdaspur, Tabiji, Makrera, Kharua, Indore, Akola, Padegaon, Coimbatore, Koilpatti, Nandayal, Hagari, Anakapalle, Surat, Delhi.
Humid	...	From Shahjahanpur, Ranchi, Nagpur, Powarkhera, Labhandi, Chandkhuri, Waraseoni, Kheri-Adhartal, Samalkot, Berhampur, Chinsura.

Per-humid	...	From Kangra, Dacca, Rangpur, Jorhat, Karimganj, Sylhet, Sirsi, Taliparamba.
Calcareous	...	From Peshawar, Sakrand, Karachi, Padrauna, Pusa.
Black	...	From Hagari, Nandayal, Koilpatti, Padegaon, Kharua, Indore, Akola, Nagpur, Powarkhera, Labhandi, Kheri-Adhartal.
Brown	...	From Anakapalle, Samalkot, Surat, Tabiji, Kangra, Chinsura, Rangpur, Sylhet, Delhi.
Red	...	From Coimbatore, Taliparamba, Sirsi, Chandkhuri, Waraseoni, Ranchi, Dacca, Jorhat.
Pink & grey	...	From Berhampur, Makrera, Mirpurkhas, Haripur-Hazara, Mianwali, Lyallpur, Lahore, Gurdaspur, Shahjahanpur, Karimganj.

As the field observations did not always help in demarcating the horizons of the profile, one foot soil samples from each profile were conveniently collected down to a depth of 5 ft. This collection was made in the months of February and March of 1937. Altogether 43 such soil profiles were examined from uncultivated lands. As far as possible the soil profiles collected represented different areas. The soil properties studied refer to individual soil samples only.

EXPERIMENTAL

The following methods of determination were found satisfactory and finally adopted after giving trials to several of the more common methods in vogue.

Total exchange capacity. By Schollenberger and Dreibelbis' [1930] neutral N-ammonium acetate method; the amount of NH_4 adsorbed was estimated.

Exchangeable bases. Na, K and Mg in the ammonium acetate leachate obtained by Schollenberger's method, and Ca according to Hissink's [1923] method.

Na was calculated by subtracting the amount of K from the sum of Na+K. Exchangeable H was not directly estimated. Account was taken of the soluble cations.

*p*H was determined by the Biilmann's [1927] quinhydrone electrode using as reference Veibel's solution which is a KCl.HCl mixture having a constant *p*H 2.03. For alkaline soils, the *p*H was determined by means of the antimony electrode using the modification and formula given by Puri [1932].

DISCUSSION

The results are given in tabular form in the appendix.

Thirty-three out of forty-three soils examined contain free $CaCO_3$, the amount of which varies greatly. The highly calcareous soils occur mostly in the arid and semi-arid regions, excepting those from Pusa, which fall in the humid region. It is natural that in the humid and per-humid regions the high precipitation will tend to dissolve the bases; in fact, the acid soils occur in these regions. The calcareous soils have generally a high base exchange capacity and a higher SiO_2/Al_2O_3 ratio than those of the acid soils. The *p*H values are high and above 7.0. In some of the samples, where the $CaCO_3$ content is small, the reaction is just below 7.0.

Profiles from Kangra, Shahjahanpur, Jorhat, Karimganj, Sylhet, Dacca, Rangpur, Chinsura, Sirsi, and Taliparamba contain no $CaCO_3$ and the *p*H is on the acidic side ranging from 4.03 to to 6.93, excepting profiles from Shahjahanpur and Chinsura in which the reaction of the soils is alkaline. In the case of profile from Ranchi the first three layers are acidic and contain no $CaCO_3$, but the lower two layers are slightly alkaline and contain very small amounts of $CaCO_3$. The soils from these profiles excepting those from Chinsura have low b.e.c. (base exchange capacity) and the SiO_2/Al_2O_3 ratios vary from 1.80 to 2.74.

From the data it is possible to distinguish three groups of profiles: (1) those in which the b.e.c. of the soil gradually increases downwards — these include the profiles from Gurdaspur, Mirpurkhas, Nagpur, Jorhat, Dacca, Surat, Nandayal,

Berhampur, and Delhi, (2) those in which the b.e.c. of the soil gradually decreases downwards—these include the profiles from Kangra, Karachi, Padrauna, Kheri-Adhaital, Powarkhera, Rangpur, Sirsi, Padegaon, Coimbatore, Taliparambe, Hagari, Samalkot, and Anakapalle; and (3) those in which the b.e.c. of the soil has a maximum value in some intermediate depths which are usually confined to the third and the fourth layers—these include profiles from Haripur-Hazara, Lahore, Shahjahanpur, Ranchi, Akola, Waraseoni, Labhandi, Chandkhuri, Indore, Kharua, Makrera, Tabiji, Karimganj, Sylhet, Koilpatti and Pusa. There are a few profiles from Peshawar, Lyallpur, Mianwali, and Chinsura in which the b.e.c. remains almost constant. The profile from Sakrand shows a minimum b.e.c. of the soil at the second and the third foot.

The variations in the content of clay (given in the appendix) which generally makes the highest contribution towards the b.e.c. are almost similar to the b.e.c. in the three groups with, however, some exceptions. They are discussed later. Clay is the product of weathering or decomposition of rocks and is likely to vary in different profiles due to climatic variations or the parent rock. This variation is reflected in the magnitude of the b.e.c. of the clay. Thus a montmorillonitic clay will have a higher b.e.c. than a kaolinitic clay. The b.e.c. of the soil also will vary for the same reason, and in a given profile the variations may be due both to the nature and the content of the clay. As the clay contents in most cases vary in a manner similar to the b.e.c., it is likely that either eluviation or illuviation of the clay has taken place.

Of the exchangeable bases, Ca is the major constituent. The variation of this exchangeable cation in the profile is similar to the b.e.c. Mg comes next in amount and its percentage is particularly high in the black types of soils. Mg is a constituent of the lattice of many clay minerals and its predominance is an indication that the soils contain magnesian minerals. Whatever may be the relative distribution of Ca in the entire profile, Mg generally shows an increase downwards. The removal of Mg from the complex by leaching is perhaps less active downwards. It is also to be noted that the Mg-bearing minerals are mostly located in the semi-arid regions where the chances of the removal of Mg would naturally be small. Exchangeable K hardly exceeds 1 m.e. and becomes a major constituent in only two soils from Berhampore (Madras) and Chandkhuri (Central Provinces). Exchangeable Na, as already pointed out, has been determined by difference. It will naturally include accumulated errors of several measurements. But as it would appear from the data, exchangeable Na is high in some of the saline soils of the arid and semi-arid regions and in the black and black cotton soils. Some of the latter types of soil contain sodium salts, but the experimental error will obviously be high in the case of these soils having high b.e.c. and other exchangeable bases.

Columns 10 and 11 of the table in the appendix give respectively the values of the b.e.c. calculated per 100 gm. of clay and the SiO_2/Al_2O_3 ratios of the clay fractions. In calculating the values of the b.e.c., it has been assumed that it is contributed solely by the clay fraction. The organic matter content being generally small, the assumption may be partly justified, but these values are likely to be misleading particularly in cases where the percentage of clay is small, so that the contribution of even a small amount of organic matter and also of silt might be appreciable. Instances of such cases are the soils from Sakrand, Karachi, Padrauna, Jorhat, Tabiji, Rangpur and Pusa. The very high values of the calculated b.e.c. of the clays in the profiles from Sakrand, Karachi, Tabiji and Rangpur may be due to this.

According to the variation of the b.e.c. per 100 gm. of clay the profiles may be grouped under three heads: (i) (a) the b.e.c. of the clay gradually decreases downwards attaining in some cases a more or less constant value, (b) the b.e.c. decreases sometimes abruptly to very low values; (ii) the b.e.c. increases downwards; and (iii) the b.e.c. remains almost unchanged.

To group (i) (a) belong the profiles from Haripur-Hazara, Gurdaspur, Kangra, Lyallpur, Mirpurkhas, Shahjahanpur, Tabiji, Dacca, Chinsura, Coimbatore, Hagari, and Delhi. The alteration in the b.e.c. is not generally associated with a change in the com-

position of the clay fraction as judged from the ratio of SiO_2/Al_2O_3. The higher b.e.c. of the top soils and its gradual decrease downwards are perhaps due to the presence of organic matter, the content of which generally decreases downwards.

Profiles from Sylhet, Sirsi, Taliparamba, Koilpatti, Samalkot, and Anakapalle belong to group (i) (b). Of these, the soils from the first three are highly acidic, those from the other three are alkaline. The influence of organic matter alone does not explain the large decrease. In the first three probably a decomposition of the complex takes place, although there is nothing in the SiO_2/Al_2O_3 ratios to indicate the existence of such processes. The low values of the b e.c. particularly in the samples from lower horizons of profiles from Sylhet, Sirsi, Taliparamba and Anakapalle suggest kaolinisation. A similar process is probably responsible for the low b.e.c. of the clay in the profiles from Ranchi, Waraseoni and Chandhkuri. The profiles from Koilpatti, Samalkot and Anakapalle, especially the last two which show alkaline reaction, contain only small amounts of $CaCO_3$, showing that the 'reserve' base status is low, possibly as a result of the solvent action of the percolating solutions.

To group (ii) belong the profiles from Nagpur, Kheri-Adhartal, Indore, Makrera and Karimganj. From the available data it is not easy to find a reasonable explanation of the observed increase at lower depth. However, an alteration in the mineralogical make-up of the complex in the different horizons of the profiles may be responsible for the observed variations.

In profiles from Peshawar, Lahore, Mianwali, Ranchi, Akola, Waraseoni, Labhandi, Chandkhuri, Kharua, Padegaon, Surat, Nandayal, and Berhampur which belong to group (iii) the b.e.c. remains almost constant, showing evidently that the composition of the clay has not materially changed and the influence of organic matter is almost uniform throughout the profile.

The exchange properties of the soils from the different places and their variations down the profile have been discussed above in relation to the chemical and other properties of the clay complex. It is interesting to see how the base exchange properties of the soils vary in the different climatic zones and according to the colour of the soil. In this comparative study the average values of the different determinations have been conveniently used. Sometimes the values within a particular zone or of a soil of a given colour show wide divergences, and it may not be justified in such cases to calculate the average values.

TABLE I

Total base exchange capacity in m. e. per 100 gm. of soil or clay (on climatic basis)

Depth	Arid		Semi-arid		Humid		Per-humid		Calcareous	
	Soil	Clay	Soil	Clay	Soil	Clay	Soil	Clay	Soil	Clay
1st ft.	9.3	61.2	34.0	91.7	26.9	71.2	9.5	61.2	9.5	109.6
2nd „	10.7	59.1	37.5	92.8	25.6	57.3	10.0	41.7	7.8	102.8
3rd „	10.9	53.1	35.5	81.1	26.7	59.3	10.6	39.4	6.6	84.4
4th „	11.4	45.9	34.1	80.1	27.8	65.1	9.9	33.0	6.8	92.8
5th „	10.9	45.4	32.4	81.7	26.5	60.7	9.3	38.6	8.1	114.7

TABLE II

Total base exchange capacity in m. e. per 100 gm. of soil or clay (on colour basis)

Depth	Black		Brown		Red		Pink and grey	
	Soil	Clay	Soil	Clay	Soil	Clay	Soil	Clay
1st ft.	45.2	77.5	20.2	102.8	11.9	45.6	8.6	57.0
2nd "	45.8	76.0	17.4	69.2	13.7	40.0	10.9	56.9
3rd "	45.6	73.3	18.1	64.5	12.3	34.6	12.0	53.8
4th "	41.9	70.8	20.4	64.1	12.2	36.0	11.8	50.6
5th "	38.3	65.6	19.0	67.2	107	38.8	1.1	49.6

Tables I and II give respectively the average values of the b.e.c. of the soil and the clay isolated from it in the different climatic zones and their variations according to the colour of the soil. The values for both the soil and the clay decrease in the various zones in the order: semi-arid> humid> arid> perhumid; and according to colour the same values decrease in the order: brown> black> pink and grey> red. The average b.e.c.'s of the soils down the profile do not show much variation, although, while considering the individual profiles, appreciable variations were noticed. There is, however, a general tendency of the b. e. c. of the clays to decrease, as also observed previously.

TABLE III

Soil reaction, exchangeable bases and base exchange capacity of soils

Soil group	Per-humid	Humid	Semi-arid	Arid	Red	Pink and grey	Brown	Black	Calcareous
*p*H	5.21	6.84	7.72	7.35	5.66	7.20	6.72	7.67	7.54
Exchange capacity	9.5	26.9	34.0	9.3	11.9	8.6	20.2	48.5	9.5
Exchangeable calcium	3.17	18.67	25.79	5.96	5.73	5.63	13.93	38.40	6.10
Total exchangeable bases	5.48	25.36	34.72	9.55	9.75	8.57	19.10	48.20	7.36

Table III gives the average values of the *p*H, exchangeable Ca, total exchangeable bases and the b.e.c. of the surface soils tabulated on both climatic and colour bases. A regular variation is not observed, but, in general, the soils from semi-arid and arid zones and those having black and pink or grey colour have alkaline reaction, whereas those from humid and per-humid zones and those having red and brown colours are acidic, the acidity being pronounced in the case of per-humid and red soils. Exchangeable Ca is, according to expectation, relatively large in the soils having high *p*H and small in those of low *p*H. A similar variation is observed in the case of the total exchangeable bases, the soils of arid and semi-arid regions and those having black and pink or grey colour and a high *p*H being completely base-saturated.

TABLE IV

Percentage exchangeable bases in terms of the base exchange capacity

Exchangeable base	Arid	Semi-arid	Humid	Per-humid	Calcareous	Black	Brown	Red	Pink and grey
Ca	64.5	67.2	72.6	28.0	69.4	81.6	66.5	44.7	65.2
Mg	16.1	19.7	18.6	12.8	10.8	23.3	16.3	13.5	14.3
Na	19.6	9.2	5.0	5.6	6.3	9.4	4.1	10.9	13.0
K	4.8	1.5	3.4	3.1	4.3	1.6	2.4	4.7	5.3

The relative percentages of the exchangeable bases in the soils of the different climatic zones and those having different colours are shown in Table IV. Exchangeable Ca constitutes the largest proportion in all the zones excepting those from the per-humid region and the red soils. Exchangeable Mg is low in the soils of the per-humid zone and the red soils compared with those of the remaining zones excepting, however, the calcareous soils, where exchangeable Mg has the lowest value. Exchangeable K varies from 1.5 to 5.3 per cent and exchangeable Na which has been calculated by difference is relatively high especially in the arid soils and in red and pink or grey soils.

SUMMARY

Soil profiles, 43 in number, collected from all over India have been examined with regard to the *p*H and the contents of the exchangeable bases, base exchange capacity of the soil samples and the variation of these properties with depth. According to the variation of the base exchange capacity of the soil and of the clay, three groups of soil profiles have been distinguished. The variations in these three groups have been discussed in the light of the possible nature of the clay mineral and its content. Exchangeable Ca constitutes the major element, then comes Mg, followed by Na and K in order. Mg is particularly high in black and black cotton types of soils and Na in saline soils. Thirty-three out of forty-three soil profiles contain $CaCO_3$ and these soils have alkaline reaction. The rest are acidic. The calcareous soils have generally a high base exchange capacity, whereas the acidic soils possess a low b.e.c.

The soil profiles which naturally fall in different climatic and colour divisions are also distinguished by their base exchange properties.

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Appendix

Exchangeable bases, pH, etc. of soils

Depth in ft.	Clay percentage	$CaCO_3$ percentage	*p*H	M. E. Exchangeable bases per 100 gm. of soil: Ca	Mg	K	Na	Total ex. cap.	B. E. C. per 100 gm. clay	$\frac{SiO_2}{Al_2O_3}$
Arid										
					Mirpurkhas—Sind					
0—1	16.24	9.86	7.34	6.25	3.09	0.27	1.70	8.17	50	2.73
1—2	18.43	9.43	7.48	5.50	3.25	0.39	1.24	8.14	44	2.64
2—3	27.32	8.25	7.63	8.30	4.45	0.24	1.30	11.64	42	2.71
3—4	38.68	6.35	7.64	9.67	5.17	0.38	2.00	13.79	35	2.58
4—5	40.10	5.77	7.81	9.20	5.36	0.14	1.83	14.07	35	2.62
					Mianwali—Punjab					
0—1	13.58	6.36	7.31	3.10	0.87	0.78	0.47	5.56	41	3.18
1—2	12.94	4.80	7.51	5.30	0.76	1.00	2.00	7.43	57	3.16
2—3	12.13	6.48	7.67	4.72	0.58	1.05	0.85	6.43	53	3.30
3—4	11.71	10.55	7.91	3.95	0.47	0.65	1.44	4.86	41	3.5[illegible]
4—5	7.24	0.55	7.94	2.40	0.62	0.67	1.48	5.30	73	2.81
					Lyallpur—Punjab					
0—1	9.89	0.66	7.59	5.55	0.16	0.32	0.50	7.10	72	3.09
1—2	12.40	1.15	7.10	6.60	0.14	0.59	0.96	8.40	64	3.36
2—3	11.92	0.30	6.56	5.05	0.15	0.59	1.30	7.60	63	3.18
3—4	13.84	0.90	6.46	5.95	0.16	0.52	0.70	8.55	61	3.20
4—5	12.59	0.29	6.35	5.40	0.17	0.55	1.10	7.50	59	3.86
					Haripur-Hazara—Punjab					
0—1	21.10	8.68	7.14	8.95	1.73	0.22	4.26	15.37	73	2.78
1—2	28.80	5.06	7.16	9.40	3.05	0.19	2.53	18.90	65	2.95
2—3	30.48	4.77	7.04	12.50	1.18	0.22	4.06	17.80	56	2.91
3—4	35.21	2.63	7.03	8.72	1.03	0.67	7.91	18.40	52	3.02
4—5	36.10	3.70	7.15	10.60	1.88	0.66	4.30	16.70	46	2.94
Semi-arid										
					Lahore—Punjab					
0—1	17.66	1.92	8.21	7.70	0.20	0.50	0.80	9.90	56	2.92
1—2	21.80	1.44	7.66	8.55	0.34	0.45	0.53	12.30	56	2.92
2—3	26.86	1.12	7.52	9.25	0.18	0.71	—	14.50	53	2.60
3—4	24.30	1.92	8.07	8.70	0.17	0.44	—	12.55	51	2.75
4—5	19.14	4.71	8.12	9.20	0.06	0.43	—	9.95	52	2.60
					Gurdaspur—Punjab					
0—1	11.58	1.23	7.88	5.45	0.03	0.34	0.76	7.05	60	2.45
1—2	20.65	0.38	7.38	8.10	0.25	0.35	1.11	9.90	47	2.45
2—3	23.88	0.17	7.11	9.15	0.38	0.32	1.40	11.50	48	2.38
3—4	24.01	0.35	7.05	8.20	0.63	0.19	1.18	10.90	45	2.45
4—5	24.74	0.13	7.13	7.45	0.53	0.23	1.28	10.75	43	2.44
					Akola—C. P.					
0—1	57.74	10.00	7.91	36.95	11.02	0.92	3.10	49.70	86	3.73
1—2	60.48	7.66	8.39	36.54	13.61	1.03	1.61	50.03	82	3.47
2—3	62.44	8.40	8.47	33.29	13.29	0.91	5.70	53.70	86	3.68
3—4	64.14	8.80	8.57	30.40	13.84	0.90	5.81	52.60	82	3.51
4—5	64.38	11.70	8.57	25.39	13.40	0.98	6.89	52.00	80	3.89

APPENDIX

Exchangeable bases, pH, etc. of soils—cont.

Depth in ft.	Clay percentage	$CaCO_3$ percentage	*p*H	M. E. Exchangeable bases per 100 gm. of soil					B.E.C. per100 gm. clay	$\frac{SiO_2}{Al_2O}$
				Ca	Mg	K	Na	Total ex. cap.		
Semi-arid				*Indore—C. I.*						
0—1	65.40	4.70	7.78	44.60	7.09	0.75	1.31	48.57	74	3.16
1—2	66.00	2.50	7.81	42.80	7.19	0.80	2.07	50.71	76	3.97
2—3	64.50	0.93	7.53	39.02	9.29	0.39	2.27	53.14	82	3.48
3—4	61.30	1.30	7.41	37.96	9.95	0.91	2.90	52.00	84	3.22
4—5	47.30	2.57	7.67	38.26	12.43	0.50	1.04	49.71	105	3.32
				Kharua—C. I.						
0—1	52.70	2.98	7.51	41.19	1.90	0.78	1.26	45.00	85	3.63
1—2	52.78	6.00	7.45	44.36	1.92	0.64	2.04	50.71	96	3.65
2—3	54.84	6.64	7.38	42.75	2.27	0.78	2.41	49.00	89	3.56
3—4	53.11	6.16	7.60	43.04	2.37	0.67	2.05	49.50	93	3.57
4—5	44.32	5.68	7.63	34.16	2.06	0.55	2.29	40.50	90	3.39
				Makrera—Ajmer-Merwara						
0—1	8.36	1.85	6.65	4.60	1.55	0.62	2.20	9.79	117	3.00
1—2	13.67	0.21	6.75	6.51	2.04	0.57	0.42	10.86	79	2.96
2—3	15.51	0.16	6.80	11.05	2.66	0.54	1.51	13.14	84	3.07
3—4	14.79	17.70	6.98	10.94	2.84	0.29	—	13.36	90	2.77
4—5	8.16	14.66	7.00	8.14	2.59	0.85	3.24	10.71	131	2.89
				Tabiji—Ajmer-Merwara						
0—1	5.04	1.03	7.15	3.00	1.10	—	1.96	6.28	124	2.81
1—2	6.05	2.22	6.85	3.75	0.84	0.49	1.72	6.36	105	2.49
2—3	6.86	1.64	7.57	2.30	1.74	0.29	1.22	6.78	98	2.70
3—4	9.30	2.90	7.86	2.45	2.54	0.36	1.38	7.11	76	2.93
4—5	3.21	1.13	8.43	0.25	2.89	0.55	0.41	3.16	98	2.92
				Padegaon—Bombay						
0—1	74.75	9.80	7.97	48.00	15.22	1.16	5.42	67.14	89	4.37
1—2	76.13	7.00	8.19	44.56	15.14	1.17	4.51	68.00	89	4.29
2—3	76.92	8.20	8.03	41.59	15.43	1.53	8.37	66.86	86	4.65
3—4	70.00	7.70	7.98	40.30	15.68	0.96	6.74	59.21	84	4.80
4—5	74.29	9.80	7.55	30.41	12.95	0.35	12.14	60.00	80	4.45
				Surat—Bombay						
0—1	47.10	1.25	7.17	40.82	8.27	0.53	1.76	48.56	103	3.13
1—2	43.00	0.41	7.21	41.82	7.45	0.45	2.07	53.64	121	3.69
2—3	43.10	0.57	7.22	43.52	9.13	0.50	0.53	53.07	123	3.65
3—3½	40.30	0.62	7.14	41.52	9.53	0.62	0.49	53.70	133	3.45
3½—4½	43.00	0.57	7.09	42.71	9.93	0.46	0.65	54.14	126	3.88
				Coimbatore—Madras						
0—1	31.67	1.05	7.05	21.4	6.0	0.61	3.8	32.3	102	2.10
1—2	37.26	0.97	6.80	17.1	6.7	0.57	6.4	34.4	92	3.01
2—3½	38.74	19.00	7.18	17.3	3.9	0.35	5.4	27.0	69	2.86
3½—5	26.95	19.40	7.03	10.7	4.7	0.22	5.5	21.1	78	3.33
				Koilpatti—Madras						
0—1	62.90	2.48	8.05	44.0	14.6	0.64	0.4	57.4	91	3.83
1—2	64.98	1.92	8.11	43.9	12.8	0.59	5.0	60.3	92	3.88
2—3	72.52	3.73	7.30	46.7	10.6	0.48	2.0	59.8	82	3.87
3—4	71.14	4.13	7.14	35.7	13.5	0.37	3.6	53.2	74	4.05
4—5	71.69	3.87	7.15	13.5	17.3	0.14	6.0	36.9	51	4.24

APPENDIX

Exchangeable bases, pH, etc. of soils—cont.

Depth in ft.	Clay percentage	$CaCO_3$ percentage	*p*H	M. E. Exchangeable bases per 100 gm. of soil: Ca	Mg	K	Na	Total ex. cap.	B.E.C. per 100 gm. clay	SiO_2 / Al_2O_3
Semi-arid				*Hagari—Madras*						
0—1	43.95	7.10	8.75	37.6	8.9	0.33	2.9	51.5	117	3.83
1—2	52.79	9.30	8 60	36.2	9.6	0.27	4.5	51.2	97	3.16
2—3	59.06	7.76	8.01	32.1	9.6	0.25	7.1	49.7	84	3.28
3—4	54.89	5.43	7.95	28.3	10.9	0.23	6.5	48.5	88	3.47
4—5	52.21	0.70	8.49	25.5	11.8	0.29	8.2	47.9	91	3.17
				Nandayal—Madras						
0—1	57.29	3.94	8.47	31.6	10.9	0.46	6.1	50.0	87	3.37
1—2	61.45	2.80	8.58	28.5	12.7	0.40	9.4	51.1	83	3.17
2—3	64.55	3.40	8.71	25.4	15.9	0.31	11.5	55.1	85	3.19
3—4	65.94	4.47	9.16	22.4	18.3	0.29	13.6	56.1	85	3.38
4—5	66.40	4.78	9.15	20.1	20.3	0.26	16.7	58.3	87	3.04
				Anakapalle—Madras						
0—1	9.48	0.09	7.91	12.4	4.4	0.38	0.5	17.1	180	3.18
1—2	17.06	0.28	7.63	7.6	2.9	0.60	0.3	10.3	60	3.15
2—3	24.10	0.18	7.89	2.4	1.1	0.27	0.4	4.2	17	3.09
3—4	27.71	0.08	8.17	3.1	1.4	0.28	0.3	4.3	15	3.29
4—5	26.28	0.15	7.93	2.1	1.0	0.05	0.1	2.9	11	3.31
				Delhi						
0—1	10.33	1.03	7.30	7.60	2.13	0.34	0.02	9.30	90	3.84
1—2	18.45	0.27	7.01	8.65	1.38	0.32	0.19	12.70	68	3.36
2—3	24.04	0.13	6.98	10.65	1.80	0.44	0.68	15.55	64	3.30
3—4	24.27	0.42	7.16	13.40	2.58	0.35	0.25	16.60	68	3.63
4—5	22.86	0.71	7.41	12.20	2.26	0.40	0.28	16.90	73	3.64
Humid				*Shahjahanpur—U. P.*						
0—1	18.58	—	8.00	4.25	0.03	0.15	0.76	7.80	42	2.74
1—2	20.40	—	7.68	7.30	0.27	0.24	0.90	12.20	59	2.21
2—3	24.70	—	7.33	7.26	0.43	0.32	1.00	12.55	50	2.11
3—4	25.14	—	7.27	7.41	0.13	0.36	1.31	11.85	47	2.09
4—5	21.06	—	7.21	6.40	0.22	0.29	0.91	8.85	42	2.12
				Ranchi—Bihar						
0—1	42.22	—	6.57	5.75	0.24	0.53	2.09	10.00	23	2.22
1—2	41.31	—	6.50	7.10	0.30	0.24	0.90	13.00	31	2.04
2—3	42.47	—	6.81	8.18	0.27	0.22	1.42	13.60	32	2.11
3—4	35.72	0.10	7.14	8.70	0.13	0.17	1.04	12.80	35	2.09
4—5	40.17	0.16	7.43	7.98	0.15	0.37	1.57	10.80	26	2.20
				Nagpur—C. P.						
0—1	59.55	2.73	7.31	44.15	11.89	0.93	0.44	57.14	95	3.17
1—2	63.11	0.74	7.51	43.50	8.42	0.93	1.36	54.21	86	3.51
2—3	66.32	0.74	7.38	41.30	16.79	1.61	2.94	59.43	89	3.43
3—4	65.71	0.61	7.54	36.15	19.19	0.91	5.09	60.00	91	3.54
4—5	64.46	5.45	8.04	39.60	22.29	0.84	2.84	64.40	100	3.53
				Waraseoni—C. P.						
0—1	21.67	0.23	6.46	5.44	1.26	0.49	—	8.57	39	2.49
1—2	40.35	0.07	6.95	9.14	1.46	0.31	1.11	12.42	30	2.36
2—3	40.83	0.25	7.95	10.32	2.01	0.18	2.09	14.50	35	2.36
3—4	34.40	0.39	7.56	6.59	1.51	0.26	1.03	10.00	29	2.31
4—5	22.18	0.24	7.09	3.84	1.46	0.20	0.50	6.57	29	2.27

APPENDIX

Exchangeable bases, pH, etc. of soils—cont.

Depth in ft.	Clay percentage	$CaCO_3$ percentage	*p*H	M. E. Exchangeable bases per 100 gm. of soil					B.E.C. per 100 gm. clay	$\frac{SiO_2}{Al_2O_3}$
				Ca	Mg	K	Na	Total ex. cap.		
Humid				*Labhandi—C. P.*						
0—1	60.07	0.13	6.41	31.84	7.90	0.50	1.62	40.71	67	2.75
1—2	62.47	0.03	6.47	30.64	8.20	0.59	1.40	39.43	63	2.65
2—3	61.14	0.03	6.68	29.83	8.20	0.82	2.23	43.43	71	2.81
3—4	61.59	0.08	7.68	30.28	10.77	0.82	1.45	42.14	68	3.11
4—5	60.61	0.13	7.75	28.43	7.59	0.45	1.26	37.43	61	3.00
				Chandkhuri—C. P.						
0—5 in.	18.12	0.40	7.16	2.50	0.77	2.88	0.33	6.85	37	2.23
5—16 ,,	48.33	0.16	6.54	6.09	3.32	4.74	1.64	16.64	34	2.06
16—28 ,,	36.36	0.30	6.68	6.21	1.90	2.38	1.35	12.07	29	2.11
28—40 ,,	31.66	0.20	7.30	6.68	1.54	1.89	0.10	9.93	31	2.07
40—52 ,,	38.65	0.16	6.87	8.16	2.60	1.95	0.80	14.28	38	3.80
52—60 ,,	34.08	0.23	6.64	7.28	2.24	2.21	1.38	13.64	40	2.11
				Kheri-Adhartal—C. P.						
0—1	49.35	0.45	7.51	34.92	5.41	0.58	1.06	38.72	78	2.96
1—2	51.01	0.33	7.40	35.07	6.67	0.53	0.74	39.40	77	2.47
2—3	42.35	2.99	7.40	33.63	7.31	0.51	0.86	37.65	88	3.13
3—4	31.86	3.56	7.45	27.72	6.95	0.43	1.16	32.04	100	3.41
4—5	24.10	2.41	7.31	25.37	5.95	0.43	1.46	27.50	114	3.30
				Powarkhera—C. P.						
0—1	57.50	0.50	6.68	40.78	5.34	0.93	1.81	48.86	85	3.13
1—2	52.28	0.77	6.99	40.78	5.32	0.94	0.94	46.71	89	2.99
2—3	59.69	0.43	7.17	38.13	5.26	0.79	1.56	45.57	76	3.23
3—4	51.98	0.57	7.23	35.83	4.30	0.79	2.20	44.43	85	3.29
4—5	62.24	0.84	7.46	36.07	4.16	0.82	2.38	44.00	70	3.19
				Chinsura—Bengal						
0—1	50.61	—	6.39	23.80	8.11	1.20	1.11	35.64	70	2.84
1—2	53.72	—	7.31	25.35	5.51	1.02	2.01	34.80	64	2.75
2—3	55.85	—	7.70	24.85	6.07	1.38	2.06	33.93	60	2.91
3—4	58.47	—	7.79	24.15	6.04	0.67	3.09	36.21	61	3.14
4—5	62.47	—	7.74	28.80	5.11	1.07	1.15	35.57	56	2.96
				Samalkot—Madras						
0—1	24.88	0.50	7.06	23.1	9.2	0.45	0.4	32.8	131	3.40
1—2	36.62	0.59	8.52	7.1	2.8	0.15	—	9.2	25	3.34
2—3	36.18	0.51	8.78	8.7	3.4	0.23	—	11.5	31	3.16
				Berhampur—Madras						
0—1	12.84	0.06	6.05	2.92	0.92	0.33	0.85	4.29	33	3.99
1—2	21.79	—	6.12	5.02	1.74	1.00	0.28	8.00	36	3.14
2—3	29.86	0.10	6.93	6.62	2.38	2.20	0.56	12.00	40	3.24
3—4	30.45	0.07	7.08	8.67	2.20	2.78	0.92	14.30	46	3.05
4—5	41.21	0.17	7.13	11.42	3.00	3.23	1.62	16.30	39	3.05

APPENDIX

Exchangeable bases, pH, etc. of soils—cont.

Depth in ft.	Clay percentage	$CaCO_3$ percentage	*p*H	M. E. Exchangeable bases per 100 gm. of soil: Ca	Mg	K	Na	Total ex. cap.	B.E.C. per 100 gm. clay	$\frac{SiO_2}{Al_2O_3}$
				Kangra—Punjab						
Per-humid										
0—1	11.55	—	6.93	10.25	0.06	0.35	0.82	12.80	110	2.58
1—2	13.75	—	6.77	9.25	0.06	0.28	0.46	11.95	86	2.60
2—3	13.53	—	6.77	6.55	—	0.22	0.50	8.90	65	2.69
3—4	11.51	—	6.81	6.80	0.39	0.35	0.64	9.10	79	2.48
4—5	12.38	—	6.38	6.05	0.23	0.18	0.47	8.40	67	2.27
				Jorhat—Assam						
0—1	6.80	—	4.26	0.05	0.44	0.32	2.45	4.85	71	2.12
1—2	8.98	—	4.10	—	0.10	0.23	0.48	7.00	77	1.97
2—3	10.74	—	4.05	—	0.66	0.25	0.23	6.30	58	2.03
3—4	9.78	—	4.03	—	0.63	0.26	0.48	7.14	73	2.00
4—5	6.00	—	4.10	—	0.86	0.21	0.31	7.46	124	1.80
				Karimganj—Assam						
0—1	20.95	—	5.81	4.55	4.46	0.16	0.94	10.96	52	2.27
1—2	19.97	—	5.88	5.40	5.23	0.18	0.65	12.61	63	2.30
2—3	20.99	—	5.80	5.90	4.75	0.28	1.05	13.25	63	2.31
3—4	16.04	—	5.91	4.85	4.00	0.28	0.80	9.86	61	2.31
4—5	14.02	—	6.22	4.85	3.98	0.25	0.92	11.04	78	2.31
				Sylhet—Assam						
0—1	11.69	—	4.84	1.90	0.42	0.23	0.26	9.14	78	2.05
1—2	32.30	—	4.45	2.07	1.05	0.24	0.18	14.68	45	1.97
2—3	48.06	—	4.17	1.90	0.76	0.40	0.57	26.57	55	2.25
3—4	81.08	—	3.94	—	0.82	0.53	0.52	15.43	19	2.08
4—5	54.83	—	4.14	—	0.83	0.59	0.74	11.71	21	2.19
				Dacca—Bengal						
0—1	19.93	—	5.69	3.10	1.01	0.34	1.04	7.75	38	2.32
1—2	39.55	—	4.64	2.08	0.83	0.39	0.82	10.18	25	2.29
2—3	46.47	—	4.74	2.58	1.91	0·50	0.21	12.75	27	2.27
3—4	44.96	—	4.94	3.45	2.25	0.36	0.49	13.95	31	2.38
4—5	45.82	—	5.24	3.95	2.60	0.30	0.70	12.15	26	2.43
				Rangpur—Bengal						
0—1	6.41	—	5.69	2.52	0.85	0·65	1.03	10.43	162	1.37
1—2	5.08	—	5.83	0.48	0.08	0.70	0.55	2.71	53	1.97
2—3	0.59	—	5.96	—	0.42	0.36	0.16	2.21	374	3.04
3—4	1.83	—	5.97	Having 96 per cent coarse sands, soils were not examined for exchangeable bases						1.44
4—5	0.90	—	6.06							1.39
				Sirsi—Bombay						
0—1	17.23	—	3.78	1.25	0.30	0.52	0.21	10.86	63	1.98
1—2	21.85	—	4.17	2.38	0.75	0.42	0.17	12.36	56	1.89
2—3	27.80	—	4.20	2.20	0.85	0.10	0.35	7.68	27	2.01
3—4	29.50	—	4.12	2.45	0.95	0.15	0.46	8.02	27	1.94
4—5	21.29	—	4.14	2.63	1.04	0.12	0.59	9.00	42	1.90

APPENDIX

Exchangeable bases, pH, etc. of soils—concld.

Depth in ft.	Clay percentage	$CaCO_3$ percentage	*p*H	M. E. Exchangeable bases per 100 gm. of soil: Ca	Mg	K	Na	Total ex. cap.	B.E.C. per 100 gm. clay	$\frac{SiO_2}{Al_2O_3}$
Per-humid				*Taliparamba—Madras*						
0—1	29.59	—	4.66	1.7	1.1	0.17	0.4	9.2	31	1.64
1—2	49.49	—	4.45	1.2	1.0	0.13	—	8.2	16	1.74
2—3	45.99	—	4.37	0.9	0.9	0.17	—	6.7	14	1.74
3—4	46.86	—	4.33	0.5	0.5	0.12	—	6.1	13	1.86
4—5	36.97	—	4.16	0.6	0.4	0.19	—	5.2	14	1.81
Calcareous				*Peshawar—N.W.F.P.*						
0—1	11.90	18.20	7.90	4.65	0.19	0.14	0.10	6.85	58	2.62
1—2	11.87	19.50	8.37	5.80	0.55	0.18	0.35	6.80	59	2.72
2—3	13.99	18.80	8.35	5.25	0.52	0.19	0.90	7.10	50	2.98
3—4	12.34	17.93	8.94	5.60	0.20	0.24	0.70	6.90	55	2.88
4—5	15.42	19.50	8.57	5.70	0.61	0.23	0.87	6.80	44	2.49
				Sakrand—Sind						
0—1	9.37	11.90	7.69	6.50	0.53	0.53	1.06	9.35	100	2.61
1—2	5.11	10.93	7.80	5.55	0.35	0.22	1.07	7.25	141	2.58
2—3	5.89	8.40	7.23	6.66	0.43	0.18	1.66	7.60	129	2.52
3—4	10.10	11.10	7.24	8.85	1.27	0.91	0.20	10.45	103	3.00
4—5	4.82	11.50	7.27	8.93	1.63	1.48	2.53	10.10	209	2.40
				Karachi—Sind						
0—1	6.57	22.45	7.14	10.35	0.62	0.66	—	17.90	292	3.33
1—2	6.25	24.27	7.73	9.50	0.74	0.47	—	14.30	228	3.40
2—3	6.86	25.80	7.52	3.75	0.40	0.52	—	11.00	160	3.42
3—4	6.78	19.00	7.32	3.60	0.25	0.52	—	10.70	154	3.68
4—5	6.06	23.00	7.40	16.05	0.69	0.72	—	18.10	298	3.52
				Padrauna—U. P.						
0—1	9.78	37.40	7.69	7.30	0.84	0.08	0.14	10.05	102	3.21
1—2	7.00	49.00	7.88	5.53	0.32	0.08	0.64	5.35	76	3.55
2—3	6.48	51.75	7.93	1.40	0.23	—	—	2.51	38	3.48
3—4	3.36	52.50	7.96	1.50	0.31	—	0.14	2.70	80	3.40
4—5	3.20	55.75	7.83	1.10	0.41	—	—	2.28	56	3.77
				Pusa—Bihar						
0—1	5.62	35.99	7.28	1.70	1.01	0.23	0.15	3.23	57	2.55
1—2	7.65	39.66	7.44	3.35	2.34	0.20	0.08	5.25	68	2.90
2—3	5.83	40.53	7.21	2.15	1.65	0.24	0.23	4.75	81	2.93
3—4	4.22	44.67	7.28	2.40	2.06	0.06	0.56	3.38	80	4.01
4—5	5.82	47.86	7.45	2.05	2.29	0.10	0.47	3.20	54	3.53

COMPARATIVE STUDIES ON INDIAN SOILS

IV. MECHANICAL ANALYSIS OF SOIL PROFILES

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Majority of Indian soils are believed to be of transported nature. In arid regions, where rivers, controlled by specific geographical conditions, have long ceased to have any influence, wind continues to play an active part in transporting and retransporting soil from one region to another. Thus the present day Rajputana, which was once a fertile portion of Indus valley is now a tract of barren sand and salt which are still being carried by the strong western wind from the Rann of Cutch [Blanford, 1876; Holland, 1908; Holland and Christie, 1909; and La Touche, 1911]. The great north Indian alluvial mantle subjected at various regions to different climatic conditions had been derived from the Himalayan system by sedimentation from the great rivers Indus, Ganges and Brahmaputra. The type of soil building through transport of mud and silt from the plains of the United Provinces to the lower regions of Bengal is still going on [Vijayaraghavacharia, 1939]. Even the oldest tract of India, the Deccan lands are not exempt from this process. For centuries the soils had been carried far and wide by wind and rains from where they had been formed so much so that the nature of the parent material of most of the soils remain untraced even today except in certain sporadic cases.

Soils of India thus being mostly of a transported nature, depth distribution of clay in the profile is of not much use for the interpretation of profile development and the resulting profile morphology. The relative proportions of groups of different particle sizes namely clay, silt and sand are however useful in classifying the various soils and their profiles on a textural basis.

The object of mechanical analysis of soils is to obtain information on particle size and to visulize the probable field behaviour of the soil. During the present work, mechanical analysis of several virgin soils from different parts of India were carried up to a depth of 5 ft. The object was to make an attempt to classify Indian soils on textural basis, to study aggregation of clay under different climatic conditions, to study distribution of clay or its movement, if any, along the profile and to draw some general conclusions about the effect of different agencies on the mechanical composition of the soils of India.

Methods of analysis

The mechanical analysis of the soils were done by Puri's [1929] NaCl dispersion method. The dispersion was secured by treatment with NaCl to convert the clay into sodium saturated condition and the grading of the particles was done by the pipette method.

For determination of water stable aggregates 15 gm. of soil were boiled with 150 c.c. of water for 15 minutes and the mixture was shaken in an end over end shaker for six hours. Total volume of the soil water suspension was then made up to 1,500 c.c. and the grading was done by the pipette method. In this case, only clay fraction was pipetted as the most active participant in the soil aggregation is clay. The difference between total clay as determined by the NaCl dispersion method and that determined by the simple water dispersion method was taken to be the amount of the clay present in an aggregated condition or the temporary or false aggregation as it is usually termed [Tiulin, 1928].

The results of analysis are given in Appendices I and II.

Classification of the soils on the basis of the mechanical fractions

An examination of the data for analyses involving NaCl dispersion shows that the values do not check with the visual textural designations such as sandy loam and clay loam. This is because soils rich in sesquioxides may show high clay contents by analysis and yet lack clayey texture and feel; also under the influence of prevailing climatic conditions, the natural aggregation of clay particles may be sufficiently strong to make the aggregates of clay particles behave like coarser particles.

It is, however, seen that in the majority of the soils the clay contents of the profiles by NaCl dispersion show some order increasing from first to third foot where usually it is maximum. A further examination of the data shows three types to occur—(a) those in which clay percentage decreases down the profile, e.g. Padrauna and Rangpur; (b) soils in which clay content increases down the profile, e. g. Gurdaspur and Chinsura; and (c) soils in which the percentage of clay is maximum at the third or fourth foot below the surface. A large number of soils comes under this group.

The relatively lower content of clay of the surface soil compared to the maximum clay content of the soils of the third and fourth foot (Lahore, Gurdaspur, Shahjahanpur, Makrera, Sylhet and Sirsi) by the NaCl dispersion method indicates eluviation. This may be the result of variations in the composition of successive alluvial deposits or of the nature of the processes subsequent to deposition. A reference to climatic factors shows that soils in the arid and the semi-arid regions having low rainfall have also low clay contents, e.g. those of Peshawar, Lyallpur, Sakrand and Makrera. The Lahore and Haripur soils are exceptions. The soils of Gurdaspur and Shahjahanpur which are under comparatively higher rainfall conditions have also a higher clay content. Rainfall has undoubtedly an important function in the weathering of soil but the original parent materials from which the transported soils were derived is also an important factor. For instance, the black soils from Akola, Labhandi, Powarkhera and Indore have a higher clay content although the rainfall is not so high. The higher clay content of Haripur soil although formed under arid conditions may be attributed to its development mainly from slates. Again, Padrauna soil, receiving almost the same amount of rainfall, is a sandy loam.

Textural variations are more marked in Assam and Bengal soils. In these two provinces, the soils are mainly alluvial and the variations in mechanical composition are predominantly determined by the nature of the deposited materials and the relief of the land. Thus Jorhat soil is much more sandy than Sylhet soil. Jorhat soil was formed by the deposits of the river Brahmaputra and being located at a higher level causes the coarser materials to be deposited. Sylhet receives the deposits laid down by the Surma River and being placed at a much lower level gets the finer deposits in large quantities. The higher content of clay down the profile in Sylhet explains also the occurrence of numerous swampy lands. Similar factors operate in distinguishing the Bengal soils from Rangpur and Chinsura. Here the differences in the nature of the deposits coming from different sources become more important.

Aggregation of clay

The significance of mechanical analysis by itself is small in throwing light on the processes of soil formation but it is of importance in giving an insight into the physical properties of soils, *in situ* and the aggregation resulting from action of chemical factors under the physical influences of the climate. The formation of aggregates, that is, the formation of compound clay particles which function as coarser particles can take place under the following conditions: (1) cohesion between clay particles, (2) cementing effect of organic matter and bacterial slime, (3) cementing effect of calcium compounds, and (4) cementing by oxides of iron and aluminium present in varying degrees of dehydration. All these factors are influenced by the prevailing climatic conditions. An idea of the amount of aggregation in various soils will be obtained from the data given in Appendix II.

Baver and Harper [1935] observed low aggregation in desert soils and podsols occurring respectively in arid and wet regions whereas a high aggregation was noticed in

chernozems which usually occur in semi-arid and semi-humid areas. The average percentage aggregation of clay $\frac{[\textit{Total clay (NaCl)—Clay (water)}]}{\textit{Total clay}} \times 100$ in the soils studied by us, excepting 3 out of 34, has been found to be 74.65±1.78 with a coefficient of variation 13.06. This shows, contrary to the observations of Baver, that aggregation in Indian soils is not effected by climatic conditions.

Influence of climate on the formation and movement of clay

The influence of climate on the formation and movement of clay has been referred to earlier. This is further exemplified by the data given in Tables I and II where the average values of the clay, silt and sand fractions have been tabulated according to the climatic divisions (Table I) and the colour of the soil (Table II).

The average data given in Tables I and II, are represented graphically in Figs. 1 and 2.

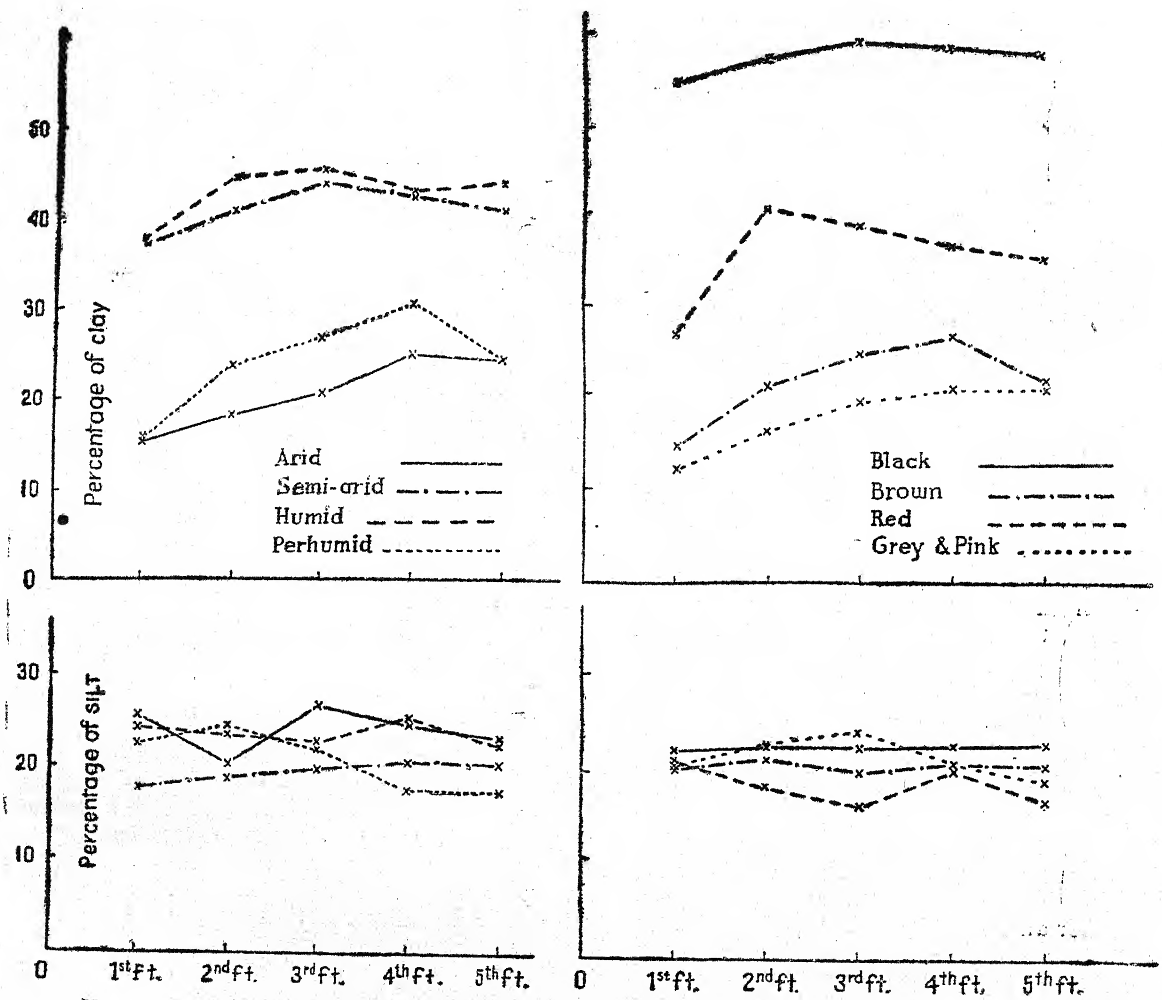

Fig. 1. Fig. 2.

FIGS. 1 and 2. Percentage of silt and clay.

TABLE I

Mechanical fractions of soils under different climatic conditions

Depth in ft.	Clay percentage	Silt percentage	Sand percentage
	Arid (4 soils)		
0—1	15.20	24.61	60.19
1—2	18.14	25.14	56.72
2—3	20.46	26.84	52.70
3—4	24.86	24.63	50.51
4—5	24.01	23.06	52.93
	Semi-Arid (15 soils)		
0—1	37.06	17.68	45.26
1—2	40.84	18.71	40.45
2—3	43.86	19.76	36.38
3—4	42.14	20.61	37.25
4—5	40.56	20.33	39.11
	Humid (11 soils)		
0—1	37.68	24.08	38.24
1—2	44.67	23.33	32.00
2—3	45.06	22.87	32.07
3—4	42.70	25.14	32.16
4—5	43.70	22.61	33.68
	Per-humid (8 soils)		
0—1	15.52	22.62	61.86
1—2	23.87	24.44	51.69
2—3	26.73	21.96	51.31
3—4	30.14	17.39	52.47
4—5	24.03	17.06	58.91

TABLE II

Mechanical fractions of soils grouped according to their colour

Depth in ft.	Clay percentage	Silt percentage	Sand percentage
	Black (13 soils)		
0—1	54.49	22.17	23.34
1—2	56.90	22.46	20.64
2—3	58.53	22.42	19.05
3—4	57.73	22.56	19.71
4—5	56.71	22.71	20.58
	Brown (12 soils)		
0—1	14.90	20.58	64.52
1—2	21.31	22.66	56.03
2—3	24.58	24.00	51.42
3—4	26.27	20.90	52.83
4—5	21.05	20.34	58.61
	Red (4 soils)		
0—1	26.79	21.02	52.19
1—2	40.24	18.16	41.60
2—3	38.08	16.09	45.83
3—4	35.93	20.01	44.06
4—5	34.29	16.42	49.29
	Grey and pink (7 soils)		
0—1	12.38	20.23	67.39
1—2	16.34	21.20	62.46
2—3	19.45	19.93	60.63
3—4	20.77	20.93	58.30
4—5	20.21	18.63	61.16

In both arid and per-humid climates maximum clay content occurs at the fourth foot. The difference between the maximum and the minimum within the profile is greater in the case of per-humid than in the case of arid regions. This may be due to mechanical downward movement of the clay with persistently greater rainfall.

Black soils containing a high amount of clay show little variation in their contents from depth to depth. It is probably due to the absence of free movements of the clay particles to any appreciable extent. The rest of the soils are characterized by low clay contents and the evidence of illuviation of clay along the profile is marked.

Silt, however, does not show variation in the profile to the same extent as clay excepting a few soils, its percentage varies on an average from about 15 to 35 and in some of the profiles the variation is reverse of that observed for clay. The sum of the percentages of sand fractions varies almost inversely to that of clay.

Summary

Data of mechanical analysis of 43 soil profiles obtained from different parts of India show that the soils could be classified into three groups: (1) soils where clay content decreases down the profile—number of such soils are small; (2) soils where clay content increases down the profile; and (3) soils where maximum clay content is observed in the third or the fourth foot depth. Majority of Indian soils fall under this last group. There are indications which show that the clay moves down mechanically to lower depths from the surface.

The amount of clay aggregated is not influenced by the prevailing climatic conditions under which the soils have been developed.

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Appendix I

Mechanical analysis of soil profiles by NaCl dispersion

Profile No.	Station	Depth in ft.	Percentage of moisture at 100° C.	Percentage of clay 0.002 mm. and below	Percentage of silt 0.002 — 0.02 mm.	Percentage of very fine sand 0.02— 0.05 mm.	Percentage of other sands above 0.05 mm.
1	Peshawar (Tarnab Farm), N. W. F. P. ...	0—1	1.07	11.90	30.85	31.70	25.55
		1—2	0.96	11.87	24.85	39.49	23.79
		2—3	1.07	13.99	28.52	34.80	22.69
		3—4	0.88	12.34	32.41	27.38	27.87
		4—5	0.83	15.42	15.14	30.08	39.36
2	Haripur Hazara, ... N. W. F. P.	0—1	1.37	21.10	44.61	19.47	14.82
		1—2	1.76	28.80	42.75	16.10	12.36
		2—3	2.22	30.48	47.45	9.81	12.25
		3—4	2.32	35.21	46.27	6.55	11.97
		4—5	2.51	36.10	42.26	11.49	10.15

APPENDIX I

Mechanical analysis of soil profiles by NaCl dispersion—contd.

Profile No.	Station	Depth in ft.	Percentage of moisture at 100° C.	Percentage of clay 0·002 mm. and below	Percentage of silt 0·002 – 0.02 mm.	Percentage of very fine sand 0.02—0·05 mm.	Percentage of other sands above 0.05 mm.
3	Lahore, Punjab ...	0—1	1.73	17.66	31.76	19.12	31.46
		1—2	1.74	21.80	34.06	18.14	26.00
		2—3	1.09	26.86	35.06	15.78	22.30
		3—4	1.02	24.30	35.80	31.50	8.40
		4—5	1.49	19.14	32.02	23.84	25.00
7	Gurdaspur, „ ...	0—1	0.83	11.58	34.60	18.98	34.84
		1—2	1.36	20.65	39.15	19.03	21.17
		2—3	1.77	23.88	40.71	8.17	29.24
		3—4	1.86	24.01	37.74	15.75	22.50
		4—5	2.02	24.74	40.65	18.04	16.57
8	Kangra, „ ...	0—1	1.36	11.55	28.82	19.46	40.17
		1—2	1.15	13.75	23.66	15.51	47.08
		2—3	1.04	13.83	13.94	18.05	54.48
		3—4	0.96	11.51	14.27	16.75	57.47
		4—5	0.88	12.38	10.53	15.61	61.48
9	Lyallpur, „ ...	0—1	1.73	9.89	16.09	12.33	61.69
		1—2	1.74	12.40	15.30	19.60	52.70
		2—3	1.10	11.92	12.70	12.15	63.23
		3—4	1.02	13.84	10.81	13.82	61.53
		4—5	1.49	12.59	14.37	17.78	55.26
10	Mianwali, „ ...	0—1	1.35	13.58	13.18	6.28	66.96
		1—2	1.12	12.94	14.66	6.47	65.93
		2—3	1.10	12.13	11.92	7.68	68.27
		3—4	0.95	11.71	12.92	6.86	68.51
		4—5	0.62	7.24	10.67	4.83	77.26
11	Sakrand, Sind ...	0—1	0·87	9.37	31.14	30.43	29.06
		1—2	0.74	5.11	21.24	41.05	32.60
		2—3	0.77	5.89	19.10	30.90	44.11
		3—4	1.20	10.10	34.18	49.10	6.62
		4—5	1.30	4.82	34.65	42.12	18.41
12	Karachi (Malir Farm), Sind ...	0—1	0.76	6.57	8.06	3.18	82.19
		1—2	0.76	6.25	8.02	4.51	81.22
		2—3	0.83	6.86	9.68	5.49	77.97
		3—4	0.87	6.78	9.04	7.42	76.76
		4—5	0.78	6.06	8.47	6.06	79.41
13	Mirpurkhas, Sind ...	0—1	1.50	16.24	24.57	16.24	42.95
		1—2	1.26	18.43	27.85	17.82	35.90
		2—3	1.93	27.32	35.28	18.15	19.25
		3—4	1.75	38.68	28.50	8.96	23.86
		4—5	2.24	40.10	24.96	8.59	26.35
18	Shahjahanpur, U. P. ...	0—1	0.40	18.58	33.06	24.78	23.58
		1—2	1.70	20.40	30.26	22.54	26.80
		2—3	1.10	24.70	35.26	26.04	14.00
		3—4	1.60	25.14	35.18	25.02	14.66
		4—5	1.20	21.06	35.66	26.28	17.00
19	Pardrauna, U. P. (Low land) ...	0—1	1.01	9.78	14.02	38.60	37.60
		1—2	1.94	7.00	15.96	60.74	16.30
		2—3	2.22	6.48	15.82	58.00	19.70
		3—4	1.85	3.36	20.64	63.24	12.76
		4—5	1.94	3.20	27.10	64.80	4.90

Appendix I

Mechanical analysis of soil profiles by NaCl dispersion—contd.

Profile No.	Station	Depth in ft.	Percentage of moisture at 100° C.	Percentage of clay 0·002 mm. and below	Percentage of silt 0·002 — 0·02 mm.	Percentage of very fine sand 0.02—0.05 mm.	Percentage of other sands above 0.05 mm.
22	Ranchi, Bihar (Up land) ...	0—1	1.46	42.22	21.07	12.83	23.88
		1—2	2.20	41.31	18.52	14.17	26.00
		2—3	2.38	42.47	18.37	15.78	23.38
		3—4	2.37	35.72	27.40	12.18	24.70
		4—5	2.12	40.17	19.29	10.21	30.33
24	Nagpur, C. P. ...	0—1	7.30	59.55	19.63	5.87	14.95
		1—2	7.79	63.11	19.74	6.81	10.34
		2—3	8.33	66.32	21.38	4.80	7.50
		3—4	8.16	65.71	21.56	4.57	8.16
		4—5	7.84	64.46	21.92	5.21	8.41
25	Akola, ,, ...	0—1	7.84	57.74	29.89	6.83	5.54
		1—2	8.18	60.48	26.30	7.70	5.52
		2—3	8.32	62.44	26.01	8.36	3.19
		3—4	8.48	64.14	23.89	8.46	3.51
		4—5	8.54	64.38	26.66	8.18	0.78
26	Waraseoni, ,, ...	0—1	1.24	21.67	28.15	6.68	43.50
		1—2	1.86	40.35	26.49	12.23	20.93
		2—3	2.51	40.83	22.77	10.26	26.14
		3—4	2.31	34.40	27.84	12.28	25.48
		4—5	1.29	22.18	25.33	15.80	36.69
27	Labhandi, ,, ...	0—1	6.57	60.07	25.78	5.74	8.41
		1—2	6.65	62.47	25.47	5.70	6.36
		2—3	6.61	61.14	23.10	4.30	11.46
		3—4	6.62	61.59	26.00	6.00	6.41
		4—5	6.38	60.61	23.46	5.38	10.55
28	Chandkhuri, ,, ...	0—5 in.	1.76	18.12	24.33	14.17	43.38
		5—16 ,,	2.97	43.33	21.46	8.74	21.47
		16—28 ,,	3.18	36.36	17.97	7.48	38.19
		28—40 ,,	3.34	31.66	18.62	4.97	44.75
		40—52 ,,	3.23	38.65	12.61	6.49	42.05
		52—60 ,,	3.16	34.08	12.60	7.64	45.68
29	Kheri-Adhartal, ,, ...	0—1	5.56	49.35	19.91	11.01	19.73
		1—2	5.90	51.01	19.55	9.24	20.20
		2—3	5.71	42.35	21.21	9.54	26.90
		3—4	3.95	31.86	19.16	8.54	40.44
		4—5	4.31	24.10	16.09	9.20	50.6
30	Powarkhera, ,, ...	0—1	6.53	57.50	25.93	8.89	7.68
		1—2	6.29	52.28	27.42	9.14	11.16
		2—3	7.63	59.69	27.90	8.06	4.35
		3—4	7.60	51.98	27.30	8.53	12.19
		4—5	7.43	62.24	26.55	11.28	—
31	Indore, C. I. ...	0—1	8.00	65.40	19.25	12.50	2.85
		1—2	8.70	66.00	22.20	10.30	1.50
		2—3	8.80	64.50	23.00	12.30	0.20
		3—4	8.80	61.30	24.60	8.00	1.10
		4—5	7.10	47.30	30.40	8.60	13.70
32	Kharua, ,, ...	0—1	6.64	52.70	22.71	11.14	13.45
		1—2	6.78	52.78	22.53	10.73	13.96
		2—3	6.65	54.84	23.14	9.00	13.02
		3—4	6.74	53.11	22.82	11.03	13.04
		4—5	5.24	44.32	27.44	10.13	18.11

APPENDIX I

Mechanical analysis of soil profiles by NaCl dispersion—contd.

Profile No.	Station	Depth in ft.	Percentage of moisture at 100° C.	Percentage of clay 0.002 mm. and below	Percentage of silt 0.002 — 0.02 mm.	Percentage of very fine sand 0.02—0.05 mm.	Percentage of other sands above 0·05 mm.
33	Makrera, Ajmere-Merwara ...	0—1	1.04	8.36	10.80	8.22	72.62
		1—2	1.39	13.67	11.12	7.94	67.27
		2—3	1.92	15.51	12.69	7.09	64.71
		3—4	1.59	14.79	19.08	11.23	54.90
		4—5	1.57	8.16	11.10	13.35	67.39
34	Tabiji, „ ...	0—1	0.79	5.04	6.65	5.64	82.67
		1—2	0.84	6.05	7.06	4.44	82.45
		2—3	0.92	6.86	7.67	5.85	79.62
		3—4	1.05	9.30	11.32	6.06	73.32
		4—5	0.44	3.21	3.82	3.82	89.15
35	Jorhat, Assam ...	0—1	0.42	6.80	8.22	15.08	69.90
		1—2	0.52	8.98	17.38	12.48	61.16
		2—3	0.64	10.74	16.54	16.34	56.38
		3—4	0.60	9.78	13.30	17.20	59.72
		4—5	0.58	6.00	8.24	15.82	69.94
36	Karimganj, „ ...	0—1	1.65	20.95	41.28	14.23	23.54
		1—2	1.85	19.97	42.38	14.67	22.98
		2—3	1.84	20.99	48.49	17.93	12.59
		3—4	1.47	16.04	34.71	18.47	30.78
		4—5	1.54	14.02	27.02	25.59	33.37
37	Sylhet, „ ...	0—1	0.76	11.69	13.30	6.65	68.36
		1—2	1.55	32.30	33.72	11.78	22.20
		2—3	1.98	48.06	40.20	8.98	2.76
		3—4	3.37	81.08	14.35	1.45	3.12
		4—5	2.24	54.83	31.30	6.14	7.73
38	Dacca, Bengal ...	0—1	1.14	19.93	26.60	24.88	28.59
		1—2	2.18	39.55	25.75	18.93	15.77
		2—3	2.52	46.47	25.24	16.00	12.29
		3—4	2.58	44.96	27.51	15.40	12.13
		4—5	2.23	45.82	24.41	15.55	14.49
39	Rangpur, „ ...	0—1	0.96	6.41	24.08	18.16	51.35
		1—2	0.70	5.08	19.98	16.96	57.98
		2—3	0.38	0.89	3.25	3.38	92.78
		3—4	0.12	1.43	0.95	1.14	96.48
		4—5	0.23	0.90	1.20	2.10	95.80
40	Chinsura, „ ...	0—1	3.83	50.61	48.78	1.51	—
		1—2	3.69	53.72	45.39	1.33	—
		2—3	3.80	55.85	43.70	0.56	—
		3—4	4.01	58.47	36·81	1.60	3.12
		4—5	4.47	62.47	35.47	2.34	—
43	Sirsi, Bombay ...	0—1	1.77	17.23	12.57	11.85	58.35
		1—2	2.21	21.85	11.75	8.32	58.08
		2—3	2.09	27.80	10.70	7.88	54.54
		3—4	2.09	29.50	11.17	9.57	49.76
		4—5	2.41	21.29	9.94	8.80	59.97
48	Padegaon, „ ...	0—1	9.58	74.75	16.36	1.11	7.78
		1—2	10.17	76.13	14.24	3.56	6.07
		2—3	9.92	76.92	14.87	2.66	5.55
		3—4	9.98	70.00	14.66	2.14	13.20
		4—5	10.48	74.29	15.41	1.90	8.40

APPENDIX I

Mechanical analysis of soil profiles by NaCl dispersion—concld.

Profile No.	Station	Depth in ft.	Percentage of moisture at 100° C.	Percentage of clay 0·002 mm. and below	Percentage of silt 0·002 — 0·02 mm.	Percentage of very fine sand 0·02—0·05 mm.	Percentage of other sands above 0.05 mm.
49	Surat, Bombay ...	0—1	8.31	47.10	19.50	2.20	31.20
		1—2	8.08	43.00	19.00	1.10	36.90
		2—3	8.26	43.10	18.30	7.70	30.90
		3—4	8.33	40.30	22.00	4.50	33.20
		4—5	8.34	43.00	17.70	4.10	35.20
50	Coimbatore, Madras ...	0—1	2.12	31.67	6.74	2.25	59.34
		1—2	3.30	37.26	7.49	1.25	54.00
		2—3½	3.47	38.74	12.53	3.52	45.21
		3½—5	2.78	26.95	12.75	4.52	55.78
51	Taliparamba, „ ...	0—1	2.00	29.59	26.11	7.35	36.95
		1—2	1.40	49.49	20.89	5.27	24.35
		2—3	0.84	45.99	17.35	8.65	28.01
		3—4	0.95	46.86	22.84	5.71	24.59
		4—5	0.82	36.97	23.83	6.92	32.28
52	Koilpatti, „ ...	0—1	7.47	62.90	11.24	3.67	22.19
		1—2	7.35	64.98	11.66	3.89	19.47
		2—3	5.96	72.52	12.12	2.98	12.38
		3—4	7.79	71.14	13.88	2.82	12.16
		4—5	7.65	71.69	10.40	3.03	14.88
54	Hagari, „ ...	0—1	2.52	43.95	19.49	3.49	33.07
		1—2	3.76	52.79	23.07	4.16	19.98
		2—3	3.82	59.06	21.83	5.20	13.91
		3—4	3.09	54.89	22 70	6.81	15.60
		4—5	3.47	52.21	25.48	8.91	13.40
55	Nandayal, „ ...	0—1	6.44	57.29	16.25	3.21	23.25
		1—2	6.91	61.45	17.40	5.16	15.99
		2—3	7.05	64.55	18.07	5.38	12.00
		3—4	7.18	65.94	17.88	4.09	12.09
		4—5	7.23	66.40	18.33	2.37	12.90
56	Samalkot, „ ...	0—1	1.30	24.88	16.61	9.12	49.89
		1—2	1.69	36.62	20.75	6.10	36.53
		2—3	1.60	36.18	19.31	5.49	39.02
57	Anakapalle, „ ...	0—1	0.84	9.48	7.26	5.85	77.41
		1—2	1.52	17.06	13.00	8.12	61.82
		2—3	2.06	24.10	14.70	8.58	52.62
		3—4	2.56	27.71	14.57	8.42	49.30
		4—5	2.51	26.28	11.70	8.83	53.19
58	Berhampore, Orissa ...	0—1	0.35	12.84	2.61	3.01	81.54
		1—2	0.87	31.79	1.61	4.03	72.57
		2—3	1.53	29.86	0.61	4.06	65.47
		3—4	1.82	30.45	11.49	6.25	51.81
		4—5	2.45	41.21	9.84	2.46	46.49
59	Pusa, Bihar ...	0—1	0.36	5.62	23.68	47.37	23.33
		1—2	0.66	7.65	31.01	43.49	17.85
		2—3	0.55	5.83	21.92	44.44	27.81
		3—4	0.52	4.22	24.93	56.69	14.16
		4—5	0.40	5.82	28.71	57.83	7.64
60	Delhi, I.A.R.I. ...	0—1	1.22	10.33	12.76	11.74	65.17
		1—2	1.34	18.45	12.39	11.55	57.63
		2—3	1.85	24.04	15.69	12.63	47.64
		3—4	1.93	24.27	15.50	13.26	46.97
		4—5	2.03	22.86	13.47	13.27	50.40

Appendix II

Clay contents of soil profiles by NaCl dispersion and simple dispersion by shaking with water

(Percentage of clays are in oven-dry basis)

Depth in ft.	Percentage of clay by NaCl dispersion (a)	Percentage of clay by simple dispersion (b)	a / b	Percentage of aggregation on clay	Depth in ft.	Percentage of clay by NaCl dispersion (a)	Percentage of clay by simple dispersion (b)	a / b	Percentage of aggregation on clay
	1. *Peshawar—Tarnab Farm*					2. *Haripur Hazara—N. W. F. P.*			
1	11.90	4.55	2.61	62	1	21.10	6.46	3.27	69
2	11.87	3.39	3.50	—	2	28.80	7.98	3.61	—
3	13.99	4.03	3.47	—	3	30.48	9.68	3.15	—
4	12.34	4.00	3.08	—	4	35.21	10.24	3.44	—
5	15.42	3.44	4.49	—	5	36.10	11.32	3.19	—
	3. *Lahore—Punjab*					7. *Gurdaspur—Punjab*			
1	17.66	5.53	3.19	68	1	11.58	6.08	1.91	47
2	21.80	6.13	3.56	—	2	20.65	5.76	3.75	—
3	26.86	8.43	3.19	—	3	23.88	6.88	3.47	—
4	24.30	5.55	4.38	—	4	24.01	8.21	2.93	—
5	19.14	6.98	2.74	—	5	24.74	6.86	3.61	—
	8. *Kangra—Punjab*					9. *Lyallpur—Punjab*			
1	11.55	4.61	2.51	60	1	—	—	—	—
2	13.75	3.12	4.40	—	2	12.40	4.38	2.83	—
3	12.53	4.16	3.25	—	3	11.92	3.00	3·98	—
4	11.51	3.55	3.24	—	4	13.84	4.14	3.35	—
5	12.38	3.35	3.70	—	5	12.59	4.10	3.07	—
	10. *Mianwali—Punjab*					11. *Sakrand—Sind*			
1	13.58	4.40	3.09	68	1	9.37	2.50	3.74	73
2	12.94	3.13	4.13	—	2	5.11	1.83	2.79	—
3	12.13	4.36	2.78	—	3	5.89	1.69	3.48	—
4	11.71	2.06	5.69	—	4	10.10	1.07	9.43	—
5	7.24	6.52	1.11	—	5	4.82	2.26	2.13	—
	12. *Karachi—Sind*					13. *Mirpurkhas—Sind*			
1	6.57	4.01	1.63	39	1	16.24	4.00	4.06	75
2	6.25	5.61	1.12	—	2	18.43	5.11	3.61	—
3	6.86	5.01	1.37	—	3	27.32	3.56	7.67	—
4	6.78	4 93	1.38	—	4	38.68	4.24	9.13	—
5	6.06	4.61	1.32	—	5	40.10	4.06	9.87	—
	18. *Shahjahanpur—U. P.*					19. *Padrauna—Low land*			
1	18.58	2.02	9.18	89	1	9.78	2.41	4.06	76
2	20.40	11.34	1.80	—	2	7.00	2.38	2.94	—
3	24.70	8.39	2 95	—	3	6.48	0.38	17.05	—
4	25.14	6.79	3.71	—	4	3.36	1.68	2.00	—
5	21.06	4.42	4.76	—	5	3.20	0.48	6·63	—

Appendix II

Clay contents of soil profiles by NaCl dispersion and simple dispersion by shaking with water—contd.

(Percentage of clays are in oven-dry basis)

Depth in ft.	Percentage of clay by NaCl dispersion (a)	Percentage of clay by simple dispersion (b)	a / b	Percentage of aggregation on clay	Depth in ft.	Percentage of clay by NaCl dispersion (a)	Percentage of clay by simple dispersion (b)	a / b	Percentage of aggregation on clay
	22. *Ranchi—Bihar Upland*					24. *Nagpur—C. P.*			
1	42.22	9.98	4.23	76	1	59.55	9.90	6.01	83
2	41.31	9.47	4.34	—	2	63.11	12.65	4.99	—
3	42.47	9.25	4.59	—	3	66.32	10.97	6.05	—
4	35.72	6.74	5.30	—	4	65.71	12.22	5.38	—
5	40.17	9.82	4.09	—	5	64.46	16.17	3.99	—
	25. *Akola—C. P.*					26. *Waraseoni—C. P.*			
1	57.74	6.79	8.50	88	1	21.67	2.69	8.05	88
2	60.48	0.76	79.58	—	2	40.35	3.65	11.05	—
3	62.44	3.15	19.83	—	3	40.83	4.30	9.51	—
4	64.14	15.19	4.22	—	4	34.40	2.65	12.97	—
5	64.38	19.89	3.24	—	5	22.18	4.36	5.09	—
	27. *Labhandi—C. P.*					28. *Chandkhuri—C. P.*			
1	60.07	17.27	3.48	71	1	33.22	6.42	5.18	65
2	62.47	19.76	3.16	—	2	36.36	15.13	2.40	—
3	61.14	16.12	3.79	—	3	31.66	6.56	4.83	—
4	61.59	12.65	4.87	—	4	38.65	3·78	10.23	—
5	60.61	11.42	5.31	—	5	34.08	10.35	3.29	—
	29. *Kheri-Adhartal—C. P.*					30. *Powarkhera—C. P.*			
1	49.35	14.64	3.37	70	1	57.50	13.79	4.17	76
2	51.01	10.15	5.03	—	2	52.28	14.27	3.66	—
3	42.36	9.88	4.28	—	3	59.69	12.21	4.88	—
4	31.86	5.44	5.86	—	4	51.98	12.26	4.24	—
5	24.10	4.83	4.99	—	5	62.24	12.36	5.04	—
	31. *Indore—C. I.*					32. *Kharua—C. I.*			
1	65.40	7.59	8.62	88	1	52.70	12.00	4.39	77
2	66.00	9.94	6.64	—	2	52.78	9.37	5.63	—
3	64.50	7.01	9.20	—	3	54.84	7.36	7.45	—
4	61.30	8.66	7.08	—	4	53.11	7.27	7.31	—
5	47.30	7.00	6.76	—	5	44.32	6.51	6.81	—
	33. *Makrera—Ajmere-Merwara*					34. *Tabiji—Ajmere*			
1	8.36	3.51	2.38	58	1	5.04	1.43	3.53	72
2	13.67	4.52	3.03	—	2	6.05	1.73	3.49	—
3	15.41	4.17	3.69	—	3	6.86	2.02	3.39	—
4	14.79	2.45	6.04	—	4	9.30	3.59	2.59	—
5	8.16	1.78	4.57	—	5	3.21	2.17	1.48	—
	35. *Jorhat—Assam*					36. *Karimganj—Assam*			
1	6.80	0.20	33.99	97	1	20.95	5.36	3.91	74
2	8.98	1.71	5.22	—	2	19.97	3.90	5.12	—
3	10.74	0.14	76.74	—	3	20.99	4.43	4.74	—
4	9.78	0.72	13.58	—	4	16.04	3.94	4.07	—
5	6.00	0.02	300.00	—	5	14.02	3.48	4.03	—

APPENDIX II

Clay contents of soil profiles by NaCl dispersion and simple dispersion by shaking with water—concld.

(Percentage of clays are in oven-dry basis)

Depth in ft.	Percentage of clay by NaCl dispersion (a)	Percentage of clay by simple dispersion (b)	a/b	Percentage of aggregation on clay	Depth in ft.	Percentage of clay by NaCl dispersion (a)	Percentage of clay by simple dispersion (b)	a/b	Pencentage of aggregation on clay
	37. *Sylhet—Assam*					38. *Dacca—Bengal*			
1	11.69	2.54	4.60	79	1	19.93	4.78	4.17	76
2	32.30	13.32	2.42	—	2	39.55	8.30	4.77	—
3	48.06	5.12	9.38	—	3	40.47	7.46	5.43	—
4	81.08	0.75	108.10	—	4	44.96	5.84	7.70	—
5	54.83	4.83	11.35	—	5	45.82	7.78	5.89	—
	39. *Rangpur—Bengal*					40. *Chinsura—Bengal*			
1	6.41	1.86	3.65	72	1	50.61	13.52	3.74	73
2	5.08	0.87	5.94	—	2	53.72	13.75	3.91	—
3	0.59	0.20	2.95	—	3	55.85	15.39	3.63	—
4	1.43	0.00	—	—	4	58.17	14.03	4.17	—
5	0.90	0.00	—	—	5	62.47	18.91	3.30	—
	43. *Sirsi—Bombay*					48. *Padegaon—Bombay*			
1	17.23	2.70	6.38	84	1	74.75	3.35	22.31	96
2	21.85	0.10	218.50	—	2	76.13	4.61	16.51	—
3	27.80	0.00	—	—	8	76.92	5.03	15.29	—
4	29.50	—	—	—	4	70.00	2.08	33.65	—
5	21.29	—	—	—	5	74.29	1.09	68.16	—
	49. *Surat—Bombay*					59. *Pusa—Bihar*			
1	47.10	9.74	4.84	79	1	5.62	4.72	1.19	16
2	43.00	9.59	4 48	—	2	7.65	2.46	3.11	—
3	43.10	9.97	4.32	—	3	5.83	3.60	1.62	—
4	40.30	8.15	4.94	—	4	4.22	1.39	3.05	—
5	43.00	3.67	11.71	—	5	5.82	1.29	4.53	—
	Delhi—I.A.R.I.								
1	10.33	3.84	3.39	63					
2	18.45	4.36	4.23	—					
3	24.04	3.79	6.34	—					
4	27.27	3.61	7.55	—					
5	22.86	3.67	6.23	—					

COMPARATIVE STUDIES ON INDIAN SOILS

V. SINGLE VALUE PHYSICAL CONSTANTS OF INDIAN SOILS

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The mechanical analysis of a soil gives the proportions of particles of different sizes from which the probable texture and related soil properties are deduced. Several soil workers have proposed from time to time different single value constants as characteristics to soil, as alternatives to mechanical analysis for assessing the probable field behaviour of a soil.

Hygroscopic coefficient [Crowther and Puri, 1924; Puri, Crowther and Keen, 1925; Puri, 1925], rate of evaporation at a given moisture content and wilting co. efficient [Alway, 1913; Shull, 1916], comparison of effective particle surface between different soils, dye absorption, heat of wetting and suction force [Haines, 1925; Haines, 1927] have been suggested as single value physical constants and have been shown to be unsuitable for use as indices of soil texture for one reason or another. Moisture equivalent has, however, been recommended by Cameron and Gallagher [1908]. Harding [1919] holds it to be an index of soil texture and consequently of its water relationships. The 'relative wetness' (soil moisture content divided by the moisture equivalent) has been used by Conrad and Veihmeyer [1929], who have shown the normal moisture capacity of the soil to be approximately the same as moisture equivalent. Briggs and Shantz [1912], Alway and Russel [1916], Smith [1917] and others have developed equations connecting moisture equivalent and clay content as found by the usual dispersion methods. As pointed out by Bodman and Mahmud [1932], Smith's equation is the only one based on actual observations while the others are derived.

The underlying idea in correlating mechanical analysis and single value constants has been to avoid the time consuming process of mechanical analysis, as a basis for physical specification. Sticky point requires no special or elaborate equipment for its determination and, if anything, is less empirical and more quickly determined. Sticky point has been used as an index of field capacity in irrigation surveys in Australia [Prescott and Poole, 1934]. Keen [1930] in a co-operative investigation reported considerable variation which ranged from 0.4 to 6.3. A new method for determining the moisture content at the sticky point has been reported by Feng Chao-lin [1939] and it is claimed to be simpler than Keen and Coutts' [1928] method.

Materials and methods

The soil profile samples mentioned in the previous sections of this series were submitted to the comparative study of moisture equivalent and sticky point in relation to the clay content of the soils. The sticky point was determined by Keen and Coutts' and by Feng Chao-lin's methods. Briggs and Maclane's [1910] method was used for the determination of moisture equivalent. The clay was determined after NaCl dispersion [Puri, 1929]. The data for clay content, moisture equivalent and sticky point determinations are presented in Appendix I.

Discussion of results

The errors in the methods (personal and method errors) were determined for three soils, each repeated on three consecutive days, and the following are variations observed:

	Keen and Coutts' method	Feng Chao-lin's method
Akola soil (K. C. Batra)	± 0.55	± 0.20
Labhandi soil (K. M. Mehta)	± 0.72	± 0.28
Nandayal soil (V. N. Prasad)	± 0.98	± 0.24

The correlation of the values for clay, moisture equivalent and sticky point have been made on the basis of climatic and colour grouping reported in the previous sections. The data for this are given in Appendices II and III.

It is seen from Appendix II that correlation is generally better in the case of soils from semi-arid and humid regions than in those from arid and per-humid regions Clay and moisture equivalent values show closer correlation with the sticky point values by Feng Chao-lin's method than with those by Keen and Coutts' method. The error in the estimation of sticky point by the former method is also lower than that by the latter method.

An attempt has been made to obtain regression equations from the coefficients of correlation to see if the approximate value of the clay can be predicted with the aid of the values for the other two constants. In most cases, this has been found to be not possible.

The chief feature of the data reported is the lack of correlation or poor or negative correlation between clay and other physical values when classified on colour or popular basis and a more definite and higher correlation under claimatic basis. In the group of calcareous soils the correlation is definitely positive compared to any of the other groupings. The definite and positive correlation between moisture equivalent and sticky point indicates definite relationship between these soil characteristics indicating their usefulness as expressions of field behaviour. Sticky point can be a more reliable index than either mechanical analysis or moisture equivalent.

It is, however, to be noted that as a general method of soil examination, none of the single value constants can replace mechanical analysis as has been shown by various previous workers. They attributed the failure to the presence of large amounts of organic matter in the soils they investigated. Our results with Indian soils in which the organic matter is negligibly low, also point to the same direction, but for other reasons. In our opinion, one of the reasons is that the dispersion treatment previous to particle grading is so drastic that the fairly strong aggregation that obtains in the field is broken. Other factors, such as the cationic composition of the clay complex, nature and amount of water soluble salts are also responsible for the lack of correlation between clay content and soil properties.

Summary and conclusions

Several single value constants have been determined in the case of a large number of Indian soils and it has been found that as a general method of soil examination none of these single value constants can replace mechanical analysis of soils.

Sticky point, however, can be a more reliable index of soil field behavior than either the mechanical analysis or moisture equivalent.

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Appendix I

Values for clay, moisture equivalent, and sticky point of soils

Name of the place		Climatic region	Popular grouping	Percentage of clay	Moisture equivalent (Average of duplicated)	Sticky point: Feng Chao-lin method	Sticky point: Keen and Coutts' method
Peshawar	...	Arid	Calcareous	11.90	15.90	21.63	23.07
Lyallpur	...	„	Indogangetic alluvium	9.89	14.30	14.70	13.55
Sakrand	...	„	Calcareous	9.37	13.10	20.53	24.70
Haripur Hazara	....	„	Brown	21.10	24.07	25.28	23.80
Mianwali	...	„	Indogangetic alluvium	13.58	9.33	14.80	13.84
Mirpurkhas	..	„	„	16.24	15.12	20.35	18.85
Karachi	...	„	Calcareous	6.57	7.27	14.45	14.64
Lahore	...	Semi-arid	Indogangetic alluvium	17.60	16.80	18.34	18.46
Gurdáspur	...	„	„	11.58	19.35	19.85	19.54
Makrera	...	„	„	8.36	10.88	16.33	16.75
Akola	...	„	Black	57.74	36.31	33.78	24.34
Indore	...	„	„	65.40	26.20	33.45	32.80
Padegaon	...	„	„	74.75	36.60	50.75	53.27
Surat	...	„	„	47.10	25.30	34.95	31.66
Kharua	...	„	„	52.70	25.88	30.63	34.12
Koilpatti	...	„	„	62.90	52.57	42.14	50.54
Hagari	...	„	„	43.95	37.05	33.41	27.60
Nandayal	...	„	„	57.29	48.60	47.58	35.04
Coimbatore	...	„	Brown	31.67	18.40	23.99	19.40
Anakapalle	...	„	„	9.48	8.09	14.83	16.75
Tabiji	...	„	„	5.04	5.00	13.80	16.45
Berhampur	...	Humid	Indogangetic alluvium	12.84	7.40	10.60	10.34
Padrauna	...	„	Calcareous	9.78	22.20	23.16	28.30
Labhandi	...	„	Black	60.07	31.97	39.40	30.10
Powerkhera	...	„	„	57.50	30.78	33.59	27.73
Nagpur	...	„	„	59.55	28.60	40.15	33.10
Kheri-Adhartal	...	„	„	49.35	27.99	32.43	26.23
Samalkot	...	„	„	24.88	20.17	22.74	24.54
Shahjahanpur	...	„	Brown	18.58	7.10	12.81	18.33
Waraseoni	...	„	„	21.67	16.52	22.81	17.48
Ranchi	...	„	Red	42.22	15.60	18.38	22.25
Chandkhuri	...	„	„	18.12	21.51	21.00	20.60
Rangpur	...	Per-humid	Indogangetic alluvium	6.41	23.10	26.35	31.80
Chinsura	...	„	Black	50.61	28.78	30.99	37.34
Dacca	...	„	Brown	19.93	16.80	33.45	32.80
Karimganj	...	„	„	20.95	28.18	27.05	27.15
Jorhat	...	„	„	6.80	11.25	18.50	20.55
Sylhet	...	„	„	11.69	11.22	15.90	18.22
Kangra	...	„	„	11.55	20.17	24.80	25.81
Taliparamba	...	„	Red	29.59	32.85	30.36	38.95
Sirsi	...	„	„	17.23	16.25	21.27	21.03

Appendix II

Correlation between different variables on basis of climatic classification

Region	Variables for correlation	Coefficient of correlation	Amount of correlation	Significance of correlation	Regression equation
Arid	Clay (X) and moisture equivalent (Y)	+0.809	High positive	Significant at 5 per cent level	X=0.701 Y+2.73
Semi-arid	do.	+0.830	do.	Significant at less than 1 per cent level	X=1.44 Y+1.12
Humid	do.	+0.774	do.	do.	X=1.734 Y−2.13
Per-humid	do.	+0.647	do.	Significant at 10 per cent level	X=1.15 Y−4.67
Arid (a)	Clay (X) and Sticky point (Y) Feng Chao-lin	+0.576	High positive	Not significant at 1 per cent 2 per cent 5 per cent and 10 per cent levels	X=0.18+0.66 Y
(b)	Clay (X) and Sticky point (Y) Keen and Coutts	+0.385	Moderately positive	—	—
Semi-arid (a)	do.	+0.970	High positive	Significant at less than 1 per cent level	X=2.07 Y−22.18
(b)	do.	+0.850	do.	do.	X=1.71 Y−9.38
Humid (a)	do.	+0.842	do.	do.	X=1.79 Y−10.91
(b)	do.	+0.680	do.	Significant at 2 per cent level	X=2.06 Y−14.41
Per-humid (a)	do.	+0.600	do.	Significant at 10 per cent level	X=1.37 Y−15.39
(b)	do.	+0.670	do.	Significant at 5 per cent level	X=1.205 Y−14.74
Arid (a)	Moisture equivalent (X) and Sticky point (Y)—Feng Chao-lin	+0.974	do.	Significant at less than 1 per cent level	X=1.24 Y−9.14
(b)	Moisture equivalent (X) and Sticky point (Y)—Keen & Coutts	+0.639	do.	Not significant at 1 per cent, 2 per cent, 5 per cent and 10 per cent level	X=0.69 Y+1.10
Semi-arid (a)	do.	+0.950	do.	Significant at less than 1 per cent level	X=1.21 Y−9.42
(b)	do.	+0.780	do.	do.	X=0.93 Y−0.19
Humid (a)	do.	+0.947	do.	do.	X=0.83 Y−0.19
(b)	do.	+0.875	do.	do.	X=1.15 Y−6.27
Per-humid (a)	do.	+0.690	do.	Significant at 5 per cent level	X=0.91 Y−2.25
(b)	do.	+0.827	do.	Significant at less than 5 per cent level	X=0.87 Y−3.57

APPENDIX III

Correlation between different variables on basis of popular grouping

Grouping	Variables for correlation	Coefficient of correlation	Amount of correlation	Significance of correlation	Regression equation
Calcareous	Clay (X)+Moisture equivalent (Y)	+0.662	High positive	Not significant at 1 per cent, 2 per cent, 5 per cent and 10 per cent levels	X=6.03+0.23 Y
Red	do.	−0.036	Negligible	—	—
Indogangetic alluvium	do.	−0.242	Low negative	—	—
Brown	do.	+0.586	High positive	Significant at 10 per cent level	X=6.57+0.64 Y
Black	do.	+0.460	do.	do.	X=35.10+0.60 Y
Calcareous (a)	Clay (X)+Sticky point (Y)—Feng Chao-lin	+0.830	do.	do.	X=0.09+0.47 Y
(b)	Clay (X)+Sticky point (Y)—Keen and Coutts	+0.658	do.	Not significant at 1 per cent, 2 per cent, 5 per cent and 10 per cent levels	X=3.84+0.25 Y
Red (a)	do.	−0.100	Low negative	—	—
(b)	do.	+0.230	Low positive	—	—
Indogangetic alluvium (a)	do.	−0.316	Moderate negative	—	—
(b)	do.	−0.447	do.	—	—
Brown (a)	do.	+0.551	High positive	Significant at 10 per cent level	X=2.13+0.67 Y
(b)	do.	+0.265	Low positive	—	—
Black (a)	do.	+0.765	High positive	Significant at less than 1 per cent level	X=10.17+1.23 Y
(b)	do.	+0.620	do.	Significant at 2 per cent level	X=27.13+0.82 Y
Calcareous (a)	Moisture equivalent (X)+Sticky point (Y)—Feng Chao-lin	+0.926	do.	Significant at 5 per cent level	X=1.50 Y−15.19
(b)	Moisture equivalent (X)+Sticky point (Y) Keen and Coutts	+0.914	do.	—	X=0.98 Y−7.60
Red (a)	do.	+0.954	do.	—	X=1.45 Y−11.53
(b)	do.	+0.921	do.	Significant at 10 per cent level	X=0.16+0.83 Y
Indogangetic alluvium (a)	do.	+0.911	do.	Significant at less than 1 per cent level	X=1.01 Y−3.30
(b)	do.	+0.882	do.	—	X=1.65+0.72 Y
Brown (a)	do.	+0.796	do.	—	X=0.88 Y−3.59
(b)	do.	+0.651	do.	Significant at 5 per cent level	X=0.91 Y−4.49
Black (a)	do.	+0.688	do.	Significant at less than 1 per cent level	X=1.83+0.85 Y
(b)	do.	+0.524	do.	Significant at 10 per cent level	X=14.75+0.53 Y

STUDIES IN GANGETIC ALLUVIUM OF UNITED PROVINCES

I. CULTIVATED SOILS OF UNAO DISTRICT

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A SYSTEMATIC soil survey of the different districts of the United Provinces has been in progress for some time with a view to study the adaptablity of different soil types to the growing of food crops and fodders and to study the suitability or otherwise of the land types to irrigation facilities now available. A large volume of data has been collected in regard to the genetical characteristics of the soils of the United Provinces and in the present contribution some selected profiles out of a total of 24 studied by us from the Unao district have been described from the point of view of their genesis.

The Unao district lies between 26.8° and 27.2° north latitude and 80.3° and 81.3° east longitude. It is bounded on the north by Hardoi, on the east by Lucknow, on the south by Rai-Bareilly, all of which belong to the Lucknow Division; and on the west by the river Ganges which separates it from the Cawnpore and Fatehpur districts. In its general aspect the district may be divided into two main divisions, viz. the low-lands or *tarai* lying along the banks of the Ganges and the uplands which extend east-wards from the high bank. Most of the agricultural lands lie on the uplands and *tarai* areas are of very little economic importance, being subjected to periodic inundations. Out of the pits reported in the present paper Hariharpur pit No. 1 is situated in the *tarai* area and the other pits on the uplands.

LITERATURE

The greater part of Northern India is occupied by alluvial deposits of the Indus, Ganges, Jumuna, Brahmaputra and their tributaries, but work in India on these alluvial soils from the genetic point of view has been extremely meagre.

Soil survey work from the point of view of agricultural suitability has been carried out in India amongst others by Harrison and Iyenger [1934], Harler [1931], Viswanath and Ramasubrahmanyan [1928], Simkins [1933], Sahasrabudhe [1929], and Mukerji and and Mukerji [1942]. Amongst the studies of soils from genetic point of view mention may be made of the work of Basu and Sirur [1938] who have studied the soils of Nira right bank and Pravara canals in Bombay Presidency, of Mukerji and Das [1940] who have studied the foot hill soils of Himalayas in the United Provinces and of Mukerji and Agarwal [1943] who have studied the soils of the Bundelkhand tract of United Provinces. It will appear from the foregoing that soil survey of the greater part of Northern India from the genetic point of view had hardly been undertaken so far.

METEOROLOGY

Complete meteorological records of the Unao district are not available. In order to give an approximate idea of the locality, the records of observations at Cawnpore are presented in Table I. Cawnpore lies next to the Unao district on the right bank of the river Ganges and the climate of both the places is very much similar.

TABLE I

Weather report of Cawnpore (Average of 10 years)

	Temperatures (Degrees F.)		Humidity (per cent)	Rainfall (inches)	Soil temperatures (Degrees C.)	
	Maximum	Minimum			8 A. M.	3 P. M.
January ...	73.0	44.0	75.7	0.41	13.5	16.1
February ...	77.7	49.7	72.0	0.37	16.1	18.6
March ...	90.7	57.7	43.7	0.19	20.8	23.3
April ...	99.9	68.2	34.1	0.39	26.6	28.7
May ...	105.9	79.6	44.0	0.22	32.6	34.3
June ...	101.1	81.4	59.4	2,40	32.7	34.1
July ...	92.5	79.1	84.5	10.13	29.0	30.3
August ...	89.2	78.1	85.9	9.5	27.4	28.9
September ..	91.1	74.4	80.0	6.7	26.9	28.9
October ...	92.0	65.9	65.0	0.32	24.1	27.1
November ...	84.7	53.2	61.0	0.02	19.7	23.2
December ...	74.3	46.5	73.3	0.74	14.3	17.6

Winters which are mild are usually frost free. On an average the maximum temperature during the months of November, December, January and February remains at 77.2°F. and minimum at 48.4°F. A few showers of rain are experienced in winter, but total precipitation during the whole period is rarely more than 2 in. The month of November remains practically rain free. Humidity during this period in the year is about 70 per cent and soil temperatures remain sufficiently high. The months of March, April, May and June are marked for high temperatures along with strong and hot winds.

The maximum temperature often rises to about 115°F. or more in the month of May. Relative humidity becomes very low and soil temperature attains at times as high a value as 45°C. On the whole this is the most arid period of the year for this locality. Rains usually start in the last week of June and continue till the third week of September. During the rainy season, the atmosphere remains highly saturated with moisture. Largest precipitation occurs in July. This period remains extremely humid. After the rains, there is tendency for the maximum temperature to rise again for a short period.

We have thus one humid and one arid period alternating with each other every year, and these climatic changes are reflected in the soil profiles. Lang's [1920], rain factor for this locality is about 31.9, which shows the aridity of the climate of the locality. N. S. quotient of Meyer [1926] for this area is 96.4, which also shows that the climate will favour desert and semi-desert type of vegetation which are usually met with in arid tropics.

METHODS OF PROCEDURE

(i) ***Survey technique.*** The details of technique adopted by us for the survey of soils in the plains are briefly enumerated below. Pits at selected places were dug up to a depth of not less than 5 ft. and each pit was broad enough for an observer to go inside and note the visual characteristics and composition of the profile. Observation on structure, texture, colour, concretions, hardness, etc. together with reactions with phenophthalein, dilute hydrochloric acid and universal soil indicator were taken ***in situ***, and samples were obtained for laboratory analysis from each horizon. Wherever horizon differentiation was not marked, samples were obtained from each foot depth. After air-drying, the colour, structure and texture were again studied for each horizon in air-dry and moisture saturated conditions.

(ii) ***Analytical methods.*** 2 mm. samples were used for the analysis detailed below. Mechanical analysis was carried out by the International method. As these soils are very poor in organic matter, pretreatment of the soils with hydrogen peroxide was, however,

omitted. Hydrochloric acid extract for the determination of insoluble residue, sesquioxides and alkaline earths was made by the Agricultural Education Association method [Crowther, 1931]. Acid and potash soluble silica were estimated by the International method [Sigmond, 1927].

In these soils no difficulty was experienced in washing the hydrochloric acid residue free of the acid, and there was found to be no need to add either sodium or ammonium chloride or nitrate. But considerable difficulty was experienced in washing the residue from potash digestion with distilled water free of alkalinity and chloride, as dispersion immediately took place and a part of the residue passed through the filter paper. We had, therefore, to wash the potash residue with 2 per cent pure sodium chloride solution free from alkalinity. For each estimation about 400 c.c. of 2 per cent sodium chloride was used. After many trials we are satisfied that this modification of the International method was very necessary at least for these soils.

From 1 : 5 soil water ratio, soil extract was filtered with the help of a Chamberlain filter candle. In this extract water soluble salts, carbonates, bicarbonates, sulphates and chlorides were estimated.

*p*H values were determined by colorimetric method with Clark & Lubb's standard indicators in 1 : 2.5 soil N. KCl extract and in doubtful cases these values were checked on a hydrogen electrode.

Organic carbon was estimated by the method due to Walkley and Black [1934]. Nitrogen was estimated by Kjeldahl's method after modification suggested by Bal [1925]. For the determination of water holding capacity Coutts' method was used [1935].

Clay was separated according to the method suggested by Robinson [Wright, 1939]. Ignited clay was fused with sodium carbonate and analysed as silicate.

For determining exchangeable bases, considerable difficulties were felt, as none of the methods were found quite suitable. After many trials the method noted below was adopted.

Ten grams of soil washed free of soluble salts were leached with normal ammonium acetate solution and total exchangeable bases were estimated as in Bray and Willhite's method [1929]. The amounts of exchangeable lime and magnesia were determined in 100 c.c. of the extract. In another 100 c.c. of ammonium acetate extract, after evaporation and ignition in dull red heat, potash was estimated by Piper's method [1934]. Exchangeable sodium was estimated by difference. In soils containing carbonates normal ammonium acetate extract gave high figures for base exchange capacity and Chapman and Kelly's [1930] method was found unsuitable due to the presence of carbonates. In the latter case exchangeable lime and magnesia were estimated by Hissink's [1923] sodium chloride method and sum of all the bases was tabulated as base exchange capacity.

Experimental

The area covered by the present survey belongs to the latter half of the upper reaches of the river Ganges. Although according to expectation, a large majority of these soils are loams, considerable areas of clay lands have also been encountered, and on this basis al the Unao soils can be classified into three major groups of sandy, loamy and clayey soils. Each of these textural units can further be classified into genetic groups, depending on the developmental characters revealed by the processes of eluviation and illuviation operating in the development of these soil profiles. Easily determined and by far the most important genetic character of the soils of Unao district is the variation of clay content in the different horizons. On this basis we have divided Unao soils into two main types, viz. soils where no signs of eluviation of clay are present and soils where eluviation of clay leads to the development of textural horizons. Although we have not met with any sub-type under the first main type, the second type has two sub-types as will be detailed presently. Besides these two types of soils we have another type of soils resembling some of the soils of the second group but certain peculiar features which necessitated their classification under a separate head. Thus we have four groups of cultivable soils belonging to three main types so far met with in the Unao district.

Type 1. The visual description of the first type of soils is given in Table II and the results of their mechanical analyses in Table III.

TABLE II

Visual description of the first type of soils

Name of pit	Depth	Description
Hariharpur pit No. I.	0-9 in.	Structureless loam and ash grey. There is some organic matter ; carbonates and alkalinity practically absent.
	9 in.-2 ft.	Grey, lighter than above, structureless. Organic matter and carbonates absent. The soil extract gives no reaction to phenolphthalein.
	2 ft.-3 ft.	Sandy, yellowish grey, Organic matter absent, although there is a trace of carbonates.
	3 ft.-5 ft.	More sandy than above: yellowish grey; structureless. Organic matter and alkalinity absent.

TABLE III

Mechanical analysis of Unao soils—Type 1 (Hariharpur pit No. I)

Horizon	B_1	B_2	C_1	C_2
Depth ...	0-9 in.	9 in-2 ft.	2 ft.-3 ft.	3 ft.-5 ft.
Coarse sand percentage ...	1.65	3.03	9.73	7.49
Fine sand percentage ...	37.35	49.50	76.51	80.40
Silt percentage ...	38.75	31.80	8.75	7.95
Clay percentage ...	19.50	13.75	3.0	2.55
Moisture equivalent percentage ...	33.25	25.94	9.5	7.21
Organic carbon percentage ...	0.76	0.43	0.27	0.32
Total N percentage ...	0.098	0.056	0.028	0.028
C/N ...	7.7	7.7	9.6	11.4

The field observations on these soil profiles do not show any clear demarcation of the constituent horizons and signs of eluviation are practically absent. A slight trace of carbonates in the third horizon can at best be considered to be due to precipitation of carbonates round feebly developed nuclei. The soil colour is ash grey and the horizon differentiation has been based on the textural character of individual layer. These soils are confined to a narrow strip of land along the left bank of the river, extending up to a breadth of 4 to 5 miles at places.

Coarses and fractions of these soils are high as compared to other alluvial soils and the clay fraction is low, showing less mechanical disintegration. There is a general tendency for clay content to decrease from the surface downwards and fine and coarse sand to increase. Carbon/nitrogen ratio tends to increase in the lower layers due to relatively lower nitrogen content. The data on the analysis of hydrochloric acid extract of these soils are given in Table IV.

TABLE IV

Chemical analyses of Unao soils—Type 1 (Hariharpur pit No. I)

Horizon	B_1	B_2	C_1	C_2
Depth ...	0-9 in.	9 in.-2 ft.	2 ft.-3 ft.	3 ft.-5 ft.
Moisture percentage ...	1.20	0.7	0.40	0.14
Loss on ignition percentage ...	4.12	2.68	0.80	0.60
Silica soluble in KOH in bulk samples percentage ...	1.25	1.40	1.48	1.36
Insoluble matter in HCl percentage	82.46	83.07	92.05	91.60
HCl soluble silica percentage ...	0.596	0.556	0.564	0.560
KOH soluble silica percentage ..	7.40	6.54	3.27	3.13
Silica in column 6 to sum of KOH and HCl soluble silica ...	15.63	19.72	38.90	36.85
Fe_2O_3 percentage ...	3.60	4.20	2.80	3.00
Al_2O_3 percentage ...	6.53	5.42	2.48	2.43
CaO percentage ...	1.05	1.53	0.83	1.19
MgO percentage ...	0.65	1.56	0.84	1.10
Sulphates percentage ...	0.07	0.06	0.10	0.07

TABLE V

Composition of 'A-Complex'—Derived data—Unao soils—Type 1 (Hariharpur pit No. I)

Depth	0-9 in.	9 in.-2 ft.	2 ft.-3 ft.	3 ft.-5 ft
Horizon	B_1	B_2	C_1	C_2
SiO_2/Al_2O_3 ...	2.06	2.21	2.61	2.57
SiO_2/R_2O_3 ...	1.53	1.48	1.52	1.44
Al_2O_3/Fe_2O_3 ...	2.84	2.02	1.39	1.27

Moisture and loss-on-ignition figures decrease with depth as a result of lower clay content. HCl insolubles increase in bottom layers, suggesting less weathering in the lower horizons, and this fact is further corroborated by lower soluble silica in C horizons. Sesquioxides are lower in C horizons although alkaline earth metals are more or less similar in both the horizons.

Relative to alumina, appreciable amounts of silica seem to have been eluviated from the surface soil downwards in the profile. The first two horizons have the same SiO_2/Al_2O_3 ratio, but the ratio increases slightly in the last two horizons. The Al_2O_3/Fe_2O_3 ratios of first two horizons are higher than those found in the last two horizons. The ratios appear to run parallel to the clay contents. This together with the morphological characters and mechanical data indicate the immature character of the Hariharpur profile.

The data on water soluble salts of the profile are presented in Table VI and exchangeable bases in Table VII.

TABLE VI

Analysis of water extract of Unao soils—Type 1

Locality	Horizon	Depth	Total water soluble solids	In mg. per cent: Carbonate Na_2CO_3	Bicarbonate $NaHCO_3$	Cl_2	SO_4	*p*H
Hariharpur pit No. I	B_1	0-9 in	80	nil	40	1.42	16.46	7.8
	B_2	9 in.-2 ft.	70	nil	50	1.42	4.12	8.2
	C_1	2 ft.-3 ft.	70	nil	60	0.71	12.34	8.2
	C_2	3 ft.-5 ft.	130	nil	60	2.13	12.34	8.3

TABLE VII

Exchangeable bases of Unao soils—Type 1

Locality	Horizon	Depth	Total exchangeable bases (m. e. percentage)	As percentage of 'S'			
				Ca	Mg	K	Na
Hariharpur Pit No. I	B_1	0-9 in.	26.4	31.44	32.20	2.05	34.31
	B_2	9 in.-2 ft.	44.5	39.10	24.66	1.08	35.16
	C_1	2 ft.-3 ft.	15.2	31.58	46.05	2.63	18.74
	C_2	3 ft.-5 ft.	33.5	36.42	20.90	0.90	41.76

Tables VI and VII depict clearly certain important developmental characteristics of these soils. Water soluble salts consisting chiefly of bicarbonates and chlorides appear to have leached down from the surface horizons. Maximum accumulation seems to have taken place in the lowest layer. This is presumably due to the sandy nature of the profile. Carbonates are absent from the profiles, whereas sulphates do not show very clear sign of translocation to the lower horizons.

The *p*H values of Hariharpur pit No. I are not constant in all depths of the profile but are more alkaline in character in the lower horizons. This increase of *p*H may be associated with the higher content of bicarbonate in the lower horizons and the consistently alkaline character of the four horizons of Hariharpur pit No. I also seem to be due to higher bicarbonate.

Exchangeable bases in the lower layers of the horizons are higher than those in the upper layers. Exchangeable potash (as percentage of 'S') is very low and bivalent bases constitute more than 50 per cent of total exchangeable bases. Exchangeable sodium is much too high and the largest amount is found associated in the zone of accumulation of soluble salts.

The clay composition of these soils is given in Table VIII.

TABLE VIII

Clay analysis of Unao soils—Type 1

Locality	Horizon	Depth	SiO_2 percentage	Al_2O_3 percentage	Fe_2O_3 percentage	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
Hariharpur pit No. 1 ...	B_1	0-9 in.	47.12	26.64	13.46	2.997	2.267	3.099
	B_2	9 in.-2 ft.	48.00	26.42	12.68	3.079	2.357	3.261
	C_1	2 ft.-3 ft.	47.64	25.52	12.68	3.176	2.412	3.154
	C_2	3 ft.-5 ft.	38.00	22.75	15.05	2.831	1.900	2.367

On a joint consideration of the data presented in Tables III to VIII, one comes to the conclusion that the soils represented by this type show some signs of immaturity, since the soil forming processes have not yet stabilized in the profile.

Type 2A. By far the large majority of soils studied by us show that clay contents assume their maxima at varying depths in the profile, and after this maximum is reached, the clay content decreases like Type 1 described in the previous pages. Thus these soils invariably show three distinct textural horizons designated by us a A, B and C. Some of these show along with the eluviation of clay, an accumulation of calcium carbonate in the 'C' horizon. Consequently we encounter two sub-types of this

major soil group, and amongst these, soils without the zone of accumulation of calcium carbonate form the majority. Visual characters and the mechanical composition of a typical formation of such sub-type, having no accumulation of calcium carbonate, are detailed in Table IX.

TABLE IX

Visual characters of a formation having no calcium carbonate

Name of pit	Horizon	Depth	Description
Mallawan	A	0 in.-1 ft.	Reddish brown; structureless loam; alkalinity and carbonates absent; very poor in organic matter.
	B_1	1 ft.-2 ft.	Same as above.
	B_2	2 ft.-3 ft.	Loam, heavier than above and more compact; grey with a trace of dark colour; carbonates and alkalinity absent.
	B_3	3 ft.-4 ft.	
	C_1	4 ft.-4 ft. 9 in.	Sandy loam, with single grain structure; organic matter and alkalinity absent.
	C_2	4 ft. 9 in.-6 ft. 3 in.	Sandy loam, lighter than above; single grained structure; organic matter absent; slight effervescence with hydrochloric acid.

TABLE X

Mechanical analysis of Unao soils—Type 2 A

Locality	Mallawan					
Horizon	A	B_1	B_2	B_3	C_1	C_2
Depth	0-1 ft.-	1 ft.- 2 ft.	2 ft.- 3 ft.	3 ft.- 4 ft.	4 ft.- 4 ft. 9. in.	4 ft. 9 in.- 6 ft. 3. in.
Coarse sand percentage ...	0.78	0.03	0.31	0.80	1.35	1.09
Fine sand percentage ...	67.02	60.99	60.77	62.50	70.04	77.50
Silt percentage ...	18.65	13.65	16.30	15.10	12.95	11.35
Clay percentage ...	13.10	18.05	21.55	20.25	14.60	9.8
Moisture equivalent percentage ...	12.67	11.36	29.18	22.21	21.25	26.16
Organic carbon percentage	0.14	0.21	0.43	0.50	0.72	0.50
Total N percentage ...	0.028	0.029	0.028	0.026	0.025	0.049
C/N ..	5.0	7.2	15.4	19.2	28.8	10.0

Soils possessing the characteristics similar to the profile described above occur in localities contiguous to the zone of occurrence of Type 1 and has an average breadth of about 20 miles comprising the whole of the highlands to the east of the flow of river Ganges.

Occurrence of small lime spots resembling star shaped white fungus mycellia are seen in the 'C' horizon in most of the profiles. The latter is one of the most outstanding secondary formation met with in the cases of profiles belonging to this sub-type and from this point of view there seems to be no great fundamental genetical difference between the two sub-types of this group. A higher clay content together with the highest amount of colloidal matter towards the lower layer of the B-horizon tend to impede proper drainage in these profiles. This layer often has a width of about 3 ft., although we have many cases where a width of about 5-6 ft has been met with. The mechanical composition of the profiles indicates marked eluviation of clay from the A-horizons and data on moisture equivalent also suggest colloidal matter accumulation in the lower layers. These figures substantiate the observation on the visual characteristics of the profiles. Moreover, the figures for organic carbon and C/N ratios of the continguous layers of all the profiles studied show that organic carbon also is trans-eluviated into lower layers. Data on chemical analysis of the profile are given in Table XI.

TABLE XI

Chemical analysis of Unao soils—Type 2 A

Locality	Mallawan					
Horizon	A	B_1	B_2	B_3	C_1	C_2
Depth	0-1 ft.	1 ft.-2 ft.	2 ft.-3 ft.	3 ft.-4. ft.	4 ft.-4ft.9in.	4 ft.9in.-6ft. 3in.
Moisture percentage ...	0.52	1.05	1.28	1.38	0.95	0.67
Loss-on-ignition percentage ...	1.59	1.69	2.13	1.78	1.89	1.38
Silica soluble in KOH in bulk sample percentage ...	1.03	2.16	1.68	1.33	1.38	1.23
Insoluble matter in HCl percentage ...	88.46	85.78	82.90	83.60	84.20	85.98
HCl soluble silica percentage ...	0.438	0.530	0.510	0.470	0.470	0.306
KOH soluble silica percentage ...	5.65	6.41	8.22	9.01	7.22	5.32
Silica in column 6 to sum of KOH & HCl soluble silica ...	16.19	31.12	19.24	14.03	17.95	21.85
Fe_2O_3 percentage ...	2.76	3.24	2.40	2.74	2.20	1.76
Al_2O_3 percentage ...	5.76	7.07	9.86	8.91	10.04	8.76
CaO percentage ..	0.25	0.19	0.26	0.26	0.30	0.25
MgO percentage ...	0.05	0.22	0.04	0.04	0.08	0.05

Moisture and loss-on-ignition figures are invariably higher in 'B' horizon. We have had already indications of higher carbon content in these layers from Table X. Insoluble matter in hydrochloric acid decreases in the B-horizon ; whereas, soluble silica tends to increase. Sesquioxides, specially alumina, show signs of eluviation from A-horizon and accumulation in B-horizon. Calcium oxide appears to have been leached out from the entire profile. The processes of eluviation and illuviation in these profiles will further be clear on an examination of the derived data in Table XII in respect of SiO_2/R_2O_3, SiO_2/Al_2O_3 and Al_2O_3/Fe_2O_3 ratios of the so-called A-complex of these soils.

TABLE XII

Composition of A complex—derived data—Unao soils—Type 2A

Locality	Horizon	Depth	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
Mallawan	A	0 1 ft.	1.79	1.37	3.27
	B_1	1 ft.-2 ft.	1.66	1.28	3.42
	B_2	2 ft.-3 ft.	1.50	1.29	6.44
	B_3	3 ft.-4 ft.	1.80	1.50	5.10
	C_1	4 ft.-4ft. 9in.	1.29	1.14	7.16
	C_2	4ft. 9in.-6ft. 3in.	1.09	0.96	7.81

From the figures of SiO_2/R_2O_3 ratios it is clear that more of the sesquioxides have been leached down as compared to silica. Of the two oxides, iron oxide seems to be less mobile than alumina, since the ratio Al_2O_3/Fe_2O_3 increases with depth and the

value in the C_2 horizon is more than double of that in the top horizon. The presence of feebly deposited iron oxide round about quartz particles in the soil profile lend further support to the above indication. From the joint study of these data, it is clear that weathering of the A-complex leads to a condition of silica and alumina leaching on a large scale in these profiles.

Data of water soluble salts are given in Table XIII and those of exchangeable bases in Table XIV.

TABLE XIII

Water extract analysis of Unao soils—Type 2A

Locality	Horizon	Depth	In mg. per cent					
			Total water soluble solids	Na_2CO_3	Na HCO_3	Cl_2	SO	pH
Mallawan	A	0-1 ft.	78	4	4	nil	12.35	7.2
	B_1	1 ft.-2ft.	56	3	3	nil	4.12	7.2
	B_2	2 ft.-3ft.	60	nil	3	nil	16.42	6.8
	B_3	3 ft.-4 ft.	42	nil	3	nil	nil	6.8
	C_1	4 ft.-4.ft.9in.	67	nil	4	nil	8.20	6.8
	C_2	4ft 9in.-6ft.3in.	305	nil	5	nil	172.4	7.8

TABLE XIV

Exchangeable bases of Unao soils—Type 2 A

Locality	Horizon	Depth	Total exchange-able bases m. e. percentage	As percentage of 'S'			
				Ca	Mg	K	Na
Mallawan	A	0-1 ft.	6.3	41.26	31.75	Trace	26.99
	B_1	1 ft.-2ft.	8.8	34.50	28.42	0.88	37.08
	B_2	2 ft.-3 ft.	10.5	37.20	23.81	Trace	38.99
	B_3	3 ft.-4 ft.	11.4	34.27	26.32	0.88	38.53
	C_1	4 ft.-4ft.9in.	9.8	33.20	25.51	Trace	41.29
	C_2	4ft.9in.-6 ft.3in.	6.9	56.61	36.23	Trace	7.16

The zone of accumulation of salts is found in the last horizon which corresponds with C_2 horizon of our soils. Chlorides seem to be absent from the profile as a whole. The highest amount of sulphate is found in the horizon where the highest accumulation of soluble salts occurs. Lower pH of this profile as compared to that of Type 1 is probably due to lower content of bicarbonates.

Exchangeable calcium has been found to be invariably high in all the profiles studied, whereas, there is considerable fluctuation in exchangeable magnesium. The amount of exchangeable potash in these soils is rather too low in all the cases and in the Mallawan profile presented in the paper exchangeable potash is practically absent. Exchangeable sodium increases in the B-horizon. It appears, therefore, that due to the high percentage of exchangeable sodium in the complex, B-horizon tends to become impermeable.

The data on clay composition of these soils are presented in Table XV.

TABLE XV

Clay analysis of Unao soils—Type 2 A

Locality	Horizon	Depth	SiO_2 Percentage	Al_2O_3 Percentage	Fe_2O_3 Percentage	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
Mallawan	A	0-1 ft.	26.10	40.24	17.16	1.10	0.87	3.67
	B_1	1 ft.-2 ft.	46.63	22.84	17.16	3.46	2.34	2.08
	B_2	2 ft.-3 ft.	30.53	42.23	16.37	1.23	0.98	4.03
	B_3	3 ft.-4 ft.	49.13	20.63	14.77	4.04	2.77	2.19
	C_1	4 ft.-4ft. 9in.	53.05	25.33	16.77	3.55	2.50	2.36
	C_2	4ft. 9in.-6ft.3in.	45.58	25.04	21.56	3.09	1.99	1.82

The profile studied at Mallawan shows that considerable leaching of silica has taken place from the surface soil of this profile. Although in general the average values of silica/alumina and silica/sesquioxide ratios increase with depth, the profile shows its silicious character throughout. It is clear from the foregoing considerations that weathering in these profiles tends to deplete the complex of silica.

The position arrived at from the general study of the data presented in Tables X to XV is that the forces leading to the development of types of soil formations represented by Type 1 profiles have been much more magnified in the formations found in Type 2 profile. We find in this case that organic carbon has invariably been eluviated into the lower horizons. Clay and colloidal matter have also been subjected to this process. Bicarbonates and sulphates have been either washed out from the profile as a whole or have gone down to the deeper layers in the profile. The complete absence of chlorides from the profiles is another evidence of the leaching processes. The character of exchangeable bases also, as a result of this leaching, has been considerably modified, so much so that in the case of the Mallawan profile we find almost complete absence of exchangeable potash. Exchangeable sodium at the same time shows gradual increase in value in the B-horizons. The chemical analysis of all soils belonging to this type show eluviation of sesquioxides from surface to the B-horizon; lime also shows the same trend; and silica arising both from silica decomposition and silica weathering indicates signs of eluviation from the surface soils. Although the behaviour in regard to magnesium oxide is rather erratic, we find its eluviation from the surface soils in Mallawan profile. The composition of the A-complex of the various horizons of these soils show intensive silica and alumina leaching.

Type 2 B. As has been stated earlier in the second sub-type we have the C-horizons differentiated from the rest of the profile by the accumulation of insoluble calcium salts in them. Such soils are met with further east of the localities where the foregoing sub-type occurs and are found at distances of more than 14 miles from the left bank of the present course of the river Ganges. These two sub-types occur together and almost under the same topographical conditions in many localities. The differences in the composition of the parent alluvial material appear, therefore, to be one of the predisposing causes leading to the development of this peculiar soil type. Descriptions of two typical profiles are given in Table XVI.

TABLE XVI

Descriptions of two typical profiles—Type 2B

Name of pit	Horizon	Depth	Description
Rahmatpur	A	0-1 ft. 4 in.	Grey structureless loam; friable, alkalinity and organic matter absent; carbonates present in traces.
	B_1	1 ft. 4 in.-2 ft. 6 in.	Structureless loam, grey slightly heavier than above, organic matter and alkalinity absent and carbonates present in traces.
	B_2	2 ft. 6 in.-2 ft. 9 in.	Structureless loam, whitish grey heavier than above, organic matter and alkalinity absent; lime *kankar* present in traces.
	C_1	2 ft. 9 in.-4 ft. 5 in.	Greyish white, structureless loam, lighter than above; slightly alkaline with marked amount of lime nodules present, organic matter absent.
	C_2	4 ft. 5 in.-5 ft. 6 in.	Greyish white, structureless sandy loam, large amount of lime nodules present, soil is slightly alkaline very poor in organic matter.
Sarauti	A	0-1 ft.	Light yellow loam, structureless but compact. Trace of carbonates present.
	B_1	1 ft.-1 ft. 8 in.	Light yellow heavy loam, carbonates present in traces, soil structure not pronounced but resembles clods.
	B_2	1 ft. 8 in.-2 ft. 4 in.	Light yellow loam, with lime nodules present in appreciable quantities. Alkalinity absent.
	C_1	2 ft. 4 in.-3 ft.	Same as above, but slightly lighter with large amount of lime nodules.
	C_2	3 ft.-3 ft. 8 in.	Light loam, greyish white with a yellowish tinge. Lime nodules present in marked quantities.

A thorough chemical, physico-chemical and mechanical study of this sub-type indicates to a great extent the extremely marked leaching in progress in the profiles represented by those studies at Rahmatpur and Sarauti villages. We find in this case as in the case of the first sub-type eluviation of clay, colloidal matter, organic carbon, silica arising both from silicate weathering and silicate decomposition, sesquioxides, alkaline bases, sulphates and chlorides. Therefore, we consider the soils presented in this subgroup to have all the essential dynamic characteristics of the soils presented under the first sub-group.

Type 3. Occurring in the same zone as Rahmatpur profile we have another type of soil formation which visually appears to have characters which differ somewhat fundamentally from those described in the foregoing pages. This soil-complex does not by any means occur over wider areas than the foregoing types and are found as isolated islands Visual description of a typical profile belonging to this type are detailed in Table XVII and data for mechanical composition, moisture equivalent and organic nitrogen and carbon contents are presented in Table XVIII.

TABLE XVII

Visual description of a typical profile—Type 3

Name of pit	Depth	Description
Ashakhera	0-1ft. 1 in.	Reddish yellow, loam, structureless.
	1 ft. 1 in.-2 ft. 3 in.	Same as above. Organic matter. Alkalinity and carbonates absent.
	2 ft. 3 in.-3 ft. 11 in.	Brownish yellow loam, heavier than above, with no pronounced structure.
	3 ft. 11 in.-4 ft. 8 in. 4 ft. 8. in.-5 ft. 4 in.	Loam, structureless, alkalinity and carbonates absent. Brownish yellow in colour.

TABLE XVIII

Mechanical analysis of Unao soils—Type 3

Locality	Ashakhera				
Horizon	A_1	A_2	B_1	C_1	C_2
Depth	0-1 ft. 1 in.	1 ft. 1 in.-2 ft. 3 in.	2 ft. 3. in.-3 ft. 11 in.	3 ft. 11 in.-4 ft. 8. in.	4 ft 8 in.-5 ft. 4 in.
Coarse sand percentage ...	1.65	0.54	0.37	0.79	0.54
Fine sand percentage ...	50.75	55.09	51.45	52.51	55.18
Silt percentage ...	16.00	12.00	13.75	11.90	15.15
Clay percentage ...	28.15	27.30	29.80	31.60	29.15
Moisture equivalent percentage ...	17.80	22.87	19.16	17.04	14.61
Organic carbon percentage ...	0.28	0.14	0.29	0.29	0.29
Total N percentage ...	0.053	0.039	0.027	0.035	0.036
C/N ...	5.3	3.7	10.6	8.2	7.9

Horizon boundaries were clear enough in the case of Ashakhera profile. In this case the soils had no structure and were reddish yellow in colour. The soils belonging to this group are mostly friable light loams.

In Ashakhera profile the clay content is sufficiently high but the soil is friable on the surface. There is a very slight indication of the translocation of clay to the lower horizons. The moisture equivalent figures in these soils are rather low and there is some indication of eluviation of organic carbon. The variation in clay content with depth was found to be silimar to that in the second type.

The results of chemical analysis of these soils are given in Table XIX.

TABLE XIX

Chemical analysis of Unao soils—Type 3

Locality	Ashakhera				
Horizon	A_1	A_2	B_1	C_1	C_2
Depth	0-1ft. 1in.	1ft.1in.-2ft. 3in	2ft.3in.-3ft.11in.	3ft.11in.-4ft. 8in.	4ft. 8in.-5 4in.
Moisture percentage ...	0.48	0.46	0.61	0.62	0.60
Loss-on-ignition percentage ...	1.99	1.64	1.11	2.23	1.71
Silica soluble in KOH in bulk samples percentage ...	2.67	2.96	2.46	—	3.94
Insoluble matter in HCl percentage ...	89.73	89.77	86.49	85.36	85.05
HCl soluble silica percentage ...	0.114	0.134	0.282	—	0.234
KOH soluble silica percentage ...	3.51	6.47	8.63	—	5.56
Silica in column 6 to sum of KOH and HCl soluble silica ...	73.76	44.85	27.61	—	67.93
Fe_2O_3 percentage ...	0.68	0.80	1.04	1.24	1.68
Al_2O_3 percentage ...	5.70	6.23	8.47	8.40	8.12
CaO percentage ...	0.15	0.14	0.15	0.14	0.14
MgO percentage ...	0.74	0.95	0.97	0.77	0.74

Hygroscopic moisture is higher in lower layers. Insoluble matter in hydrochloric acid decreases in the lower horizons. Silica soluble in 5 per cent potash are higher noi B. horizon. Particularly remarkable, however, is the high amount of silica arising out of soil decomposition in the first horizon of this profile. Iron and aluminium oxides seem to have been eluviated from the surface soils. Although on an average containing very low amunt of lime this ingredient does not show any great fluctuation between the different horizons Magnesium oxide, however, seems to have been eluviated to the second horizon.

The acid base ratios of A-complex of these soils are presented in Table XX.

TABLE XX

Composition of A-complex derived data—Unao soils—Type 3

Locality	Horizon	Depth	SiO_2/Al_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3
Ashakhera ...	A_1	0-1ft.1in.	1.07	1.00	13.14
	A_2	1ft.1in.-2ft.3in.	1.79	1.66	12.21
	B_1	2ft.3in.-3ft.11in.	1.78	1.65	12.77
	C_1	3ft 11in.-4ft.8in.	—	—	—
	C_2	4ft.8in.-5ft.4in.	1.21	1.00	0.76

In this profile we find leaching down of silica from A_1-horizons; the A-complex of the surface horizon of this profile contains very low amount of silica relative to sesquioxides Al_2O_3/Fe_2O_3 ratio shows slight accumulation of alumina in surface soils. Like the pits studied at Hariharpur we have in these cases an evidence of leaching down of iron in the profile indicating slight tendency for podsolization.

Data on water extract of these soils are presented in Table XXI.

TABLE XXI

Analysis of water extract—Unao soils—Type 3

Locality	Ashakhera				
Horizon	A_1	A_2	B_1	C_1	C_2
Depth	0-1ft.1in.	1ft.1in.-2ft.3in.	2ft.3in.-3ft.11in.	3ft.11in.-4ft. 8in.	4ft.8in.-5ft.4in.
Total water soluble solids ...	64	78	114	108	94
Na_2CO_3 (in mg. per cent)	nil	nil	nil	nil	nil
$NaHCO_3$ (in mg. per cent)	32.0	46.0	88.0	96.0	75.0
Cl_2 (in mg. per cent)	nil	nil	nil	nil	Trace
SO_4 (in mg. per cent)	24.70	4.12	4.12	8.24	12.35
pH	7.2	7.2	8.4	8.4	8.4

In Ashakhera profile water soluble salts show a zone of accumulation in the B-horizon. Bicarbonate shows high values in B_1 and C_1-horizons. Chlorides seem to be absent from the profile as a whole. The behaviour in regard to the sulphates is rather erratic. The difference in pH values between the A and B horizons of Ashakhera profile is very marked. This difference is due to the character of exchange complex of these soils, data on which are presented in Table XXII.

TABLE XXII

Exchangeable bases of Unao soils—Type 3

Locality	Horizon	Depth	Total exchange-able bases m. e. percent-age	As percentage of 'S'			
				Ca	Mg	K	Na
Ashakhera	A_1	0-1ft.1in.	7.0	55.86	35.71	8.02	0.41
	A_2	1 ft. 1in.-2 ft. 3 in.	7.3	47.54	27.40	6.58	18.48
	B_1	2 ft. 3in.-3ft. 11 in.	14.1	21.56	14.19	2.80	61.45
	C_1	3 ft. 11 in-4ft. 8 in.	11.3	19.29	13.28	4.25	63.28
	C_2	4ft. 8 in.-5 ft. 4 in.	12.1	18.02	12.40	2.58	67.00

Particularly noticeable is the fact that A_1- and A_2-horizons of Ashakhera profile contain very low amount of total exchangeable bases, which consist of nearly 75.90 per cent of calcium and magnesium cations. The high amount of exchangeable sodium in B-horizon of this profile has been due to leaching of salty solution in the past. The absolute impoverishment of the A-horizon in regard to exchangeable sodium which differentiates this group from the others will be discussed later.

The composition of the clay fractions of this profile is given in Table XXIII.

TABLE XXIII

Clay analysis of Unao soils—Type 3

Locality	Horizon	Depth	SiO_2 percent-age	Al_2O_3 percent-age	Fe_2O_3 percent-age	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
Ashakhera	A_1	0-1 ft. 1 in.	46.86	23.74	14.26	3.346	2.418	2.606
	A_2	1 ft. 1 in.-2 ft. 3 in.	46.18	28.58	14.62	2.738	2.064	3.060
	B_1	2 ft. 3 in.-3 ft. 11 in.	45.30	28.34	14.21	2.709	2.050	3.112
	C_1	3 ft. 11 in.-4 ft. 8 in.	13.74	60.04	13.86	0.388	0.338	6.782
	C_2	4 ft. 8 in.-5 ft. 4 in.	28.16	45.08	14.62	1.059	0.877	4.827

In this we find the largest amount of silica in A_1-, A_2- and B_1-horizons. In this profile the horizons which appear to have sesquioxidic character are the C_2- and C_1- horizons.

The foregoing tables make it clear that soils represented by profile studied at Ashakhera village are in fact "Degraded sodium or 'Soloti' soils". We find in these profiles slight eluviations of clay, colloidal matter, organic carbon, soluble silica, magnesia and sesquioxides, and a considerable enrichment of the clay complex in the lower horizons with sodium. The absence of exchangeable sodium in the surface soils and the presence of sodium bicarbonate in these profiles lead one, therefore, to the belief that sodium complex in the surface soils has been degraded. Since we did not find any exchangeable hydrogen in the surface soils it can further be assumed that hydrogen clay

which results according to the Sigmond's theory [1938] by hydrolysis of sodium clay has been decomposed into silica and sesquioxides. This assumption is further verified by a very low amount of total exchangeable bases in the surface soils.

Discussion

The present study of the soils of the Unao district in the United Provinces *inter alia* throws some very useful light on the dynamics of a part of the Gangetic alluvium which represents the soils of the major part of the central United Provinces.

The profile differentiations into marked horizons are absent in most of the soils of this region. In many cases, however, we have evidence of the existence of textural horizons. The C-horizons of most of these soils are very sandy. The largest amount of silica arising out of the soil decomposition is confined mostly to first two horizons. Silica soluble in 5 per cent KOH, i. e. silica arising from the weathering of silicates, is illuviated into B-horizons. Sesquioxides show signs of translocation from A-horizons, a tendency which is shared more or less by the alkaline earth minerals.

The total water soluble salt content in general of all the profiles are not very high. Bicarbonates and sulphates form the two chief anions of the water extract. The bulk of the cations in the water extract has been found to consist of sodium. A large percentage of exchangeable bases consists of calcium and its total with magnesium amounts to over 50 per cent of the total exchangeable bases in most of the cases. Exchangeable potash is extremely low, and there is an appreciable amount of exchangeable sodium in the complex. In all the cases we find the evidence of the increase of sodium cation of the complex in the B-horizons, and nowhere is its percentage less than 12. These soils are, therefore, mainly sodium soils but are conspicuous by the absence of any well developed structure in the B-horizon as has been met with in the sodium soils of other countries.

Clay analysis data presented in the body of the paper show curiously enough some very peculiar features. Silica/sesquioxide ratio for some of these soils is much too low, showing some resemblance to clay characteristics of laterites as pointed out by Martin and Doyne [1927]. But as will be shown presently these soils can by no means be classed as laterites, thus showing as has already been indicated by recent workers [Joachim and Kandian, 1941], the inapplicability of the ratios to a large variety of tropical soils. It becomes clear from the analytical data that the soil is subjected to intense disruptive action, which breaks down the clay complex and translocates the acidoid fraction.

The first sub-type of Type 2 has well developed horizons of eluviation and accumulation. From the visual descriptions it is clear that tendencies for the accumulation of calcium carbonate exist in the third horizon. The total water-soluble salts, chlorides and sulphate all go to show the effect of leaching. The exchangeable complex shows signs of gradual enrichment in sodium cations even in the C-horizon. The clay complex generally shows signs of disruption on the surface and eluviation of silica. Although these conditions show solonetz features yet no typical solonetz structure is apparent. In some of the profiles of this type we have appreciable amount of soluble salts. We have, from a thorough consideration of all the data, classified these soils under the broad group of saline alkali soils, although the profiles represented in this paper in many respects have solonetz features. The predisposing causes leading to the development of saline alkali soils must have been a saline condition of the surface-soil in the past originating in the cases of alluvial soils of Gangetic alluvium from weathering of the soil itself.

In the second sub-group of Type 2, we find an accumulation of calcium carbonate in the form of *kankar* nodules in the C-horizon. All other features are more or less similar to those found for soils belonging to the first sub-type. The processes leading to the formation of the soils of the two sub-groups of Type 2 are not very dissimilar and the cause of the occurrence of the zone of lime accumulation in the case of one sub-type must, therefore, be assigned to differences in the parent materials themselves.

We have already given an account of the immature character of the soils represented by Hariharpur 1 profile. Here, however, it could be easily seen from the data

presented that the processes of soil formation tend to a development of soil type similar in essentials to that of salty alkali soils. In view of the fact that the exchangeable complex contains more than 12 per cent sodium, it seems that the first stage of soil formation, viz. the so-called saline soils of Sigmond's [1938] first stage has been absent in the dynamics of the development of Unao soils. This could be explained by the supposition that these sodium soils of Unao are the cumulative effect of salinization and desalinization processes taking place within the same year. The immature character of the soils of first type have been fully discussed earlier and these soils may be classified as immature salty alkaline soils.

The soil formation represented by profile from Ashakhera is different from other soils of Unao district by the existence of a number of peculiar features. The absence of sodium cation from the surface soils and relatively lower amount of total exchangeable bases in these horizons together with very high amount of exchangeable sodium in the sub-soils point to a state of degradation of sodium soils. Although in Ashakhera profile the absolute values of silica/sesquioxide ratios in contiguous horizons show resemblance to podsols, we have not in this particular case detected any hydrogen clay and the base exchange complex is highly saturated. The chemical analysis of these soils also show mobilization of soluble silica, sesquioxides and lime. We therefore consider, particularly in view of reddish brown colour of the surface soils and in view of the character of A complex, these soils to be a variety of tropical Red Loams arising out of the degradation of sodium soils.

Summary

1. The soils of Unao district forming a part of Gangetic alluvium and lying on the left bank of the river have been studied from the point of view of their mechanical composition, chemical characters, total and individual water soluble salts, composition of exchangeable complex and chemical character of colloidal clay. Three genetic types of soils have been found to occur in this area.

2. The first type has been classified as immature salty alkali soils. The soils belonging to Type 2 which occupy by far the largest part of Unao district have been classified into two sub-types as salty alkali soils without zone of accumulation of calcium carbonate and salty alkali soils with a zone of accumulation of calcium carbonate. The pedological characters of the third group of soils show signs of degradation and have been classified as degraded salty alkali soils.

3. It has been suggested from a thorough study of data that the frequent occurrence of alkalinity in the soils of Unao district has been due to downward leaching of salty solutions arising primarily from soil decomposition. It has also been suggested that sodium soils on further degradation tend to assume characters of zonal soil types.

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EFFECT OF STORAGE ON RAPE-SEED AND RAPE-OIL

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Improperly stored seed undergoes deterioration rapidly and yields a crude oil of inferior quality, and a poor crude oil, in turn, yields products of low quality. Similarly oil that has suffered deterioration, through improper storage, either gives a low output of low-quality products or is totally unfit for use in the preparation of high-grade products. Thus in any scheme aiming at the establishment of oilseed-crushing industry in India on sound lines, the question of proper storage of seed and oil must occupy the centre of the stage and claim priority of attention. Unfortunately the problem of proper storage of oilseeds and oil has so far remained neglected, and this paper contains the results of experiments to assess the effect of different lengths and methods of storage on the quality of rape-seed as well as on the quality of the oil expressed from such differently stored seeds, and the effect of different lengths of storage on the quality of rape-oil itself.

The methods of analyses employed in connection with the studies reported in this paper were those given in the 1935 edition of *Methods of Analysis of the Association of Official Agricultural Chemists, U. S. A.*

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*Both the writers are to be regarded as joint authors without anyone's seniority over the other.

EFFECT OF STORAGE ON SEED

Methods and material. As preliminary studies had shown that on storage under-dry, unripe and damaged rape-seed deteriorates rapidly, and as this fact is too well-known to oilseed traders and processing establishments to need any extensive experimental corroboration, such seeds were excluded from the present studies. Consequently only dry, fully ripe, sound and fresh seeds of *toria* (*Brassica campestris* L., var *toria* D. and F.), brown-seeded *sarson* (*B.campestris* L., var. *dichotoma* Watt.), yellow-seeded *sarson* (*B. trilocularis* H. f. and T.) and *raya* (*B. juncea* H. f. and T.), which all are commercially designated as 'rape-seed', were employed in these studies. The seeds were stored in the laboratory in lidless metallic containers and in gunny bags to simulate bulk and bag storage of trade, respectively. The experiment was carried out for a period of two years, longer period having been considered unnecessary in view of the fact that normally there will be no need for oilseed-crushing establishments to carry stocks of rape-seed for more than a year, i. e. from one harvest to another.

Samples from the aforesaid two differently stored lots of seeds were withdrawn at four-monthly intervals and small portions thereof analysed for their oil and nitrogen contents. Further determinations on the oil expressed from the remaining portions of seed-samples were made in respect of specific gravity at 15.5°C., acid value, saponification value and iodine value. The figures obtained from these analyses were compared with those obtained from similar determinations made on the seeds under study at the time of starting the experiment.

Results and conclusions. Only the final figures obtained at the end of two years' storage have been given in Table I, those for intermediate periods of storage having been excluded as they exhibited no marked differences and would thus have unnecessarily increased the bulk of this paper. Alongside these final figures, those obtained in respect of original seed have also been given for comparison.

TABLE I

Effect of storage on rape-seed

Name of oilseed	Method and period of storage	Results of analyses					
		Seeds		Oil freshly expressed from seeds			
		Percentage of oil	Percentage of nitrogen	Specific gravity at 15.5°C.	Acid value	Saponification value	Iodine value
Toria	Fresh, original sample	44.24	2.98	0.915	1.36	180.6	104.5
	Stored for 2 years:						
	(a) in bulk in lidless containers	44.79	2.76	0.915	1.88	178.4	102.7
	(b) in gunny bags	44.98	3.15	0.915	1.70	179.7	102.3

TABLE I

Effect of storage on rape-seed—concld.

Name of oilseed	Method of period of storgae	Results of analyses					
		Seeds		Oil freshly expressed from seeds			
		Percentage of oil	Percentage of nitrogen	Specific gravity at 15.5°C.	Acid value	Saponification value	Iodine value
Brown-seeded *sarson*	Fresh, original sample	48.83	2.83	0.915	0.82	186.4	100.9
	Stored for 2 years:						
	(a) in bulk in lidless containers	48.04	2.97	0.915	0.77	188.8	102.8
	(b) in gunny bags	48.44	2.76	0.914	1.09	187.5	98.2
Yellow-seeded *sarson*	Fresh, original sample	48.48	3.25	0.914	0.82	191.3	101.6
	Stored for 2 years:						
	(a) in bulk in lidless containers	48.42	3.15	0.915	0.70	188.5	101.3
	(b) in gunny bags	48.06	3.22	0.915	0.87	182.1	98.8
Raya (L-18)	Fresh, original sample	40.50	3.67	0.915	2.23	193.1	106.1
	Stored for 2 years:						
	(a) in bulk in lidless containers	40.27	3.50	0.914	2.18	193.5	103.9
	(b) in gunny bags	39.06	3.67	0.915	2.87	191.7	104.4

It will be seen from Table I that the figures obtained for the seeds stored for two years, whether in bulk or in bags, do not show any appreciable differences either between themselves or from the initial values obtained in respect of the fresh, original seed-samples. Slight variations exhibited by the figures are of no practical import because they are of such a nature as fall within the limits of experimental and sampling errors The obvious conclusion, therefore, is that if dry, fully ripe, sound and fresh rape-seed is stored, whether in bulk or in bags, in well-ventilated stores, impervious to rain or seepage water, the seed does not undergo any deterioration at all for a period of two years at least. This good keeping quality of the rape-seed is attributed generally to the fact that the oil contained in it acts as a preservative. The oil probably also acts as a deterrent to insects as no insect pests are so far known to seriously attack rape-seed specifically in stores. Rats, black ants and white-ants damage the stored rape seed if they can have access to it, but their depredations can be entirely checked if the seed is stored in godowns having cemented floors, cement-plastered walls and flat ceilings, and,

if possible, having on all the four external boundaries, with no bridges across it, a small, narrow, cemented drain in which water may be kept standing continuously to prevent incursion of black ants to stores from outside.

Effect of storage on oil

Review of past work. As already stated no work has been done in India on changes that take place in rape-oil on storage. Some attention has been given in other countries to evaluate changes occurring on the oxidation of drying oils, but even there non-drying or semi-drying oils (between which two classes of oils, the rape-oil occupies an intermediate position) do not seem to have been studied from this standpoint and very little published literature exists on the subject. The only notable contribution in this direction is that of Gripper [1899] who has given characteristics of old rape-oils kept in corked bottles in full daylight from 4 to 10 years. Air had access to the oils under experiment. By working on these oils which had absorbed oxygen gradually, he adduced evidence in support of the findings of Thomson and Ballantyne [1892] on blown rape-oil to the effect that as the specific gravity and potash absorbing power increased there was a proportionate decrease in iodine absorption, and that the change was not attended by the development of any considerable amount of fatty acids. Later Procter and Holmes [1905] showed that as the time of blowing rape-oil with air at 100°C. increased, the specific gravity and refractive index of the oil increased but the iodine value decreased correspondingly.

Methods and material. As the oils obtained from seeds of the aforesaid four species of plants grouped commercially under the term rape-seed do not show much variation among themselves, only oils of *toria* and brown-seeded *sarson* were employed for experimental purposes. Samples of these oils, expressed from the seeds of these two crops obtained from a number of Agricultural Farms in the Punjab, were put in clean glass-stoppered (but not airtight) bottles which were placed in a cupboard to shut out the light. The samples were stored for a period of six years and at yearly intervals small quantities were withdrawn from the bottles and analysed for some of their physical and chemical constants. At the time of withdrawing samples no precautions were taken to exclude air which consequently had free access to the oil during this operation.

Results and conclusions. The results obtained are given in Table II, wherein values obtained for fresh oil are also added for comparison.

TABLE II

Effect of storage on rape-oil

Kind of oil	Age of oil	Specific gravity at 15.5°C.	Acid value	Saponification value	Iodine value	Remarks
Toria oil	Fresh	0.915	2.62	174.1	102.9	Average of 8 samples
	One year old	0.915	4.31	175.3	103.4	,,
	2 years old	0.916	5.09	177.8	102.3	,,
	3 years old	0.916	5.96	174.2	99.7	,,
	4 years old	0.919	7.43	179.7	98.3	Average of 7 samples
	5 years old	0.923	10.01	183.9	99.9	Average of 6 samples
	6 years old	0.925	13.60	178.9	100.2	,,
Brown *sarson* oil	Fresh	0.915	0.65	176.4	102.9	Average of 12 samples
	One year old	0.914	1.60	176.4	102.9	,,
	2 years old	0.915	2.20	178.0	102.1	,,
	3 years old	0.915	3.39	181.7	101.5	,,
	4 years old	0.917	3.96	177.7	100.5	,,
	5 years old	0.924	4.91	181.6	97.9	,,
	6 years old	0.924	8.62	179.5	99.2	,,

It will be seen from the figures given in Table II that :

(i) The Acid value has shown a progressive and marked increase with the passage of time, it having increased from 2.62 and 0.65 in fresh *toria* and *sarson* oils, respectively, to 13.60 and 8.62 in six years old oils.

(ii) There is a general tendency for the specific gravity to increase with the age of the oil, the increase being particularly discernible after the oils had become more than three years old.

(iii) As compared to fresh oil, the iodine value is lower in all samples more than one year old.

(iv) Though the saponification value has exhibited no regular trend, yet, as in all cases (excepting one in which it is equal to that of fresh oil) it is higher in old samples than in the fresh ones, it may be inferred that there is a tendency for the saponification value to increase in old samples.

The above findings are in line with those of Gripper (1899) who found that with an advance in the age of rape-oil (to which air had access) specific gravity, saponification value and soluble free fatty acids increased, while iodine value decreased.

Athawale, Duke and Mathur [1938] after examining a large number of samples from all over India suggested the following range of physical and chemical constants, among others, as characteristic of pure commercial mustard (rape) oil produced in India :

1. The specific gravity of the oil at 15.5°C./15.5°C. should not be lower than 0.912 nor higher than 0.916.
2. The saponification value of the oil should not be less than 169 nor higher than 178.
3. The iodine value of the oil should not be less than 96 nor higher than 108.
4. The acid value of the oil should not exceed 5.

Applying these criteria to the figures given in Table II, it will be seen that so far as the iodine value is concerned, the figures given both for *toria* and brown *sarson* oils fall within the range suggested above; that as regards specific gravity, both the oils come up to commercial standard up to three years of storage ; that in the matter of saponification value, *toria* oil for three years and brown *sarson* oil for two years of storage did not transgress the limits suggested above ; and that in respect of the acid value, *toria* oil for nearly two years and brown *sarson* oil for five years of storage remained within the maximum limit suggested.

Considered from the standpoint of above limits, it may be taken that, under the conditions of the experiment, both *toria* and brown *sarson* oils would pass muster as pure commercial rape-oil up to two years of storage. As already stated some air had access to these oils in this experiment, but if the air had been entirely excluded it is possible that the oils would have retained their status as pure commercial rape-oils for a considerably longer period as was found to be the case by Gripper in his studies on rape-oil to which air had no access.

Summary

The results reported in this paper represent the first attempt made in India to assess experimentally the changes that rape-seed and rape-oil undergo during storage.

Seeds of *toria* (*Brassica campestris* L., var. *toria* D. and F.), brown-seeded *sarson* *B. campestris* L., var. *dichotoma* Watt.), yellow-seeded *sarson* (*B. trilocularis* H. f. and T.) and *raya* (*B. juncea* H. f. and T.) are designated commercially as rape-seed. If dry, fully ripe, sound and fresh seeds of these plants are stored, whether in bulk or in bags, in well-ventilated stores, impervious to rain or seepage water, the seeds for a period of two years at least undergo no deterioration in quality as judged by their oil and nitrogen contents and from the determinations made in respect of the specific gravity, acid value, saponification value and iodine value of the oils expressed from them.

Toria and brown *sarson* oils when stored for a period of six years under conditions in which air had some access to them, did not undergo, for a period of two years, a change in their physical and chemical constants to such an extent as would have placed them beyond the pale of pure commercial rape-oil.

With an increase in the age of the oils, the acid value increases markedly, and the specific gravity and saponification value exhibit a tendency to increase, while the iodine value shows a tendency to decrease.

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A STUDY OF THE CHEMICAL COMPOSITION AND YIELD OF BERSEEM (*TRIFOLIUM ALEXANDRINUM*) AS INFLUENCED BY THE INTERVALS BETWEEN CUTTINGS

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Berseem is one of the most favourite fodder with owners of live-stock because it yields several cuttings of highly nutritious fodder for about six months in a year and is available in late November and continues right up to the wheat harvesting season when other green fodders are not usually available in the Punjab. In addition, it enriches the soil owing to its nitrogen fixing power.

Increasing the yield of such a useful fodder is a matter of great economic importance. The yield depends not only on the supply of water and the fertility of soil, but also upon the frequency and intervals between cuttings. Many workers, notably Paterson [1933-35], Wilsie and Takahashi [1937], and Lander [1942], report that the frequency of cutting affects both the quality and quantity of fodders and grasses. No systematic work has so far been done on berseem on these lines. An experiment was, therefore, carried out with a view to studying the relationship between the intervals of cuttings and the yield and quality of berseem, the results of which are reported in this paper.

Experimental

A piece of land measuring about one and a half acres was selected at the Lyallpur Agricultural Farm. Four treatments, viz. 15, 30, 45, 60 days' intervals between the successive cuttings were tried on the randomized block system with six replicates.

The relevant details of the experiment and the Agricultural operations carried out are given below :

A. Interval between successive cuttings 15 days.
B. " " " " 30 "
C. " " " " 45 "
D. " " " " 60 "

Size of each plot 106./25 ft. ×20.49 ft.=1/20 acre.

Preliminary cultivation

One ploughing with a furrow turning plough followed by three ploughings with the *desi* plough and subsequent tillage with horse-hoe and *sohaga* were carried out.

Date of sowing	30-9.1941
Seed rate	12 seers per acre
Previous crop	Berseem
No. of irrigations	12

Cuttings were obtained from individual plots on dates reckoned from 9.12.1941, this being the date of first common cutting in this experiment. Fresh weight of green herbage removed was recorded each time. Representative samples of fodder obtained from all the plots were chopped immediately and dried in an air-oven and ash, protein, calcium, phosphorus and potassium were estimated in each of the samples.

Methods of analysis followed were those recommended by the Associations of Official Agricultural Chemists [1940].

RESULTS

The average chemical composition of the fodder obtained from different cutting treatments is given in Table I. These data have been arrived at by dividing total quantity of individual constituents obtained per plot throughout the growing period after 9.12.1941 by the dry matter in that plot and expressing them as percentage of dry matter.

TABLE I

Average chemical composition of berseem with different intervals of cuttings

Serial No.	Plot No.	Percentage of dry matter	Percentage of oven-dried material				
			Ash	Protein	CaO	P_2O_5	K_2O
			15 days' interval (average of 9 cuttings)				
1	4	17.3	20.3	20.8	2.47	0.84	3.68
2	6	16.6	18.6	21.9	2.56	0.81	3.70
3	10	17.5	18.4	22.5	2.48	0.88	3.98
4	13	15.9	17.8	22.1	2.41	1.02	4.07
5	18	16.1	16.7	22.1	2.42	0.83	3.89
6	21	17.5	20.9	20 9	2.41	0.80	3.71
Average		16.8	18.8	21.7	2.46	0.8	3.84
			30 days' interval (average of 5 cuttings)				
7	2	12.6	15.8	20.9	2.55	0.76	
8	8	13.6	17.0	21.3	2.62	0.69	4.93
9	11	15.9	15.3	20.5	2.53	0.69	4.38
10	16	13.9	15.1	20.8	2.52	0.72	4.47
11	20	12.2	15.4	21.8	2.61	.67	4 31
12	22	13.2	14.7	20.4	2.56	0.68	4.27
Average		13.6	15.6	21.0	2.56	0.70	4.45
			45 days' interval (average of 4 cuttings)				
13	3	18 0	11.4	15.6	2.53	0.47	3.11
14	5	19.0	12.3	14.9	2.56	0.43	3.20
15	9	20.0	11.6	14.1	2.46	0.40	3.09
16	14	20.5	13.0	15.7	2.60	0.50	3.34
17	17	19.2	11.8	15.7	2.57	0.45	3.40
18	24	19.0	12.9	15.9	2.47	0.44	3.76
Average		**19.3**	**12.3**	15.3	2.53	0.45	3.32

TABLE I

Average chemical composition of berseem with different intervals of cuttings—concld.

Serial No.	Plot No.	Percentage of dry matter	Percentage of oven-dried material				
			Ash	Protein	CaO	P_2O_5	K_2O
			60 days' interval (average of 3 cuttings)				
19	1	18.0	14.1	14.3	2.52	0.45	3.45
20	7	22.3	11.3	15.3	2.62	0.42	2.66
21	12	21.3	11.9	13.6	2.52	0.37	3.14
22	15	20.5	13.4	14.0	2.38	0.45	2.92
23	19	20.9	11.7	13.5	2.33	0.42	3.23
24	23	21.4	11.1	14.9	2.53	0.44	3.20
Average		20.7	12.2	14.3	2.48	0.43	3.10
Critical difference		1.2	0.7	0.8	0.08	0.07	0.10

The layout of the experiment admitted of statistical interpretation of the results and average figures along with the critical difference are also given in the same table.

The figures showing the yield per acre of green fodder and of its various constituents obtained after 9.12.1941 are given in Table II. The data were analysed statistically but as the variations in treatments between A and B were found to be far less than those of C and D, the three degrees of freedom for treatments were further split up into three parts, one for comparison between X (A and B) and Y (C and D), another for comparison between A and B are with X and the third for comparison between C and D are within Y. Observed values of 'F' are given in this table.

TABLE II

Yield of berseem and its constituents in maunds per acre when cut at different intervals of time

Serial No.	Plot No.	Green herbage	Dry matter	Ash	Protein	CaO	P_2O_5	K_2O
			15 days' interval (total of 9 cuttings)					
1	4	103	17.8	3.62	3.70	0.44	0.150	0.66
2	6	105	17.5	3.26	3.84	0.45	0.142	0.65
3	10	81	14.1	2.60	3.18	0.35	0.124	0.56
4	13	98	15.6	2.78	3.46	0.38	0.160	0.64
5	18	87	14.0	2.34	3.10	0.34	0.116	0.54
6	21	76	13.2	2.76	2.76	0.32	0.106	0.49
Average		92	15.4	2.89	3.34	0.38	0.133	0.59
			30 days' interval (total of 5 cuttings)					
7	2	228	28.7	4.54	6.00	0.73	0.218	1.42
8	8	197	26.9	4.56	5.72	0.70	0.184	1.18
9	11	145	23.1	3.54	4.72	0.58	0.160	1.03
10	16	168	23.4	3.54	4.86	0.59	0.168	1.02
11	20	189	25.0	3.84	5.44	0.65	0.168	1.08
12	22	154	20.4	3.00	4.16	0.52	0.138	0.87
Average		180	24.6	3.84	5.15	0.63	0.173	1.10

TABLE II

Yield of berseem and its constituents in maunds per acre when cut at different intervals of time—concld.

Serial No.	Plot No.	Green herbage	Dry matter	Ash	Protein	CaO	P_2O_5	K_2O
			45 days' interval (total of 4 cuttings)					
13	3	629	113.3	12.94	17.68	2.86	0.526	3.53
14	5	597	113.1	13.88	17.68	2.89	0.488	3.62
15	9	589	117.7	13.60	16.62	2.90	0.474	3.63
16	14	644	131.7	17.18	20.66	3.43	0 664	4.39
17	17	577	111.0	13.08	17.38	2.85	0.500	3.77
18	24	496	94.2	12.18	15.02	2.33	0.412	3.54
Average		589	113.3	13.81	17.51	2.88	0.511	3.74
			60 days' interval (total of 3 cuttings)					
19	1	664	119.4	16.84	17.42	3.01	0.542	4.12
20	7	602	134.2	15.14	20.48	3 52	0.566	3.54
21	12	512	109.0	13.00	14.82	2.57	0.408	3.43
22	15	567	115.9	15.54	16.24	2.67	0.524	3.38
23	19	485	101.3	11.84	13.66	2 36	0.428	3.27
24	23	497	106.5	11.28	15.04	2.56	0.446	3.24
Average		555	114.4	13.94	16.23	2.83	0.484	3.50
Observed value of 'F'	Between 'X' and 'Y'	729	623	281	369	375	255	3090
	Within 'X'	91	212	31	99	95	25	52
	Within 'Y'........	2.5	0.02	0.7	0.1	0.1	0.7	1.3

DISCUSSION OF RESULTS

Effect of cutting treatments on chemical composition

From the data in Table I, it will be observed that with regard to their variations with different cutting treatments, the chemical constituents can be divided into two groups. The constituents of one group comprising ash, phosphorus and protein vary in a decreasing proportion with increase in the interval of cutting. The remarkable fact about the decrease is that it takes place in two distinct steps. It is significantly high between the 15 day and 30 day intervals, most marked between the 30 day and 45 day intervals, while it is hardly appreciable between 45 and 60 day interval. The other group contains calcium, potossium and dry matter. There is very little change in the calcium contents of the fodder due to different intervals between cuttings. Dry matter contents increase with increase of intervals except a significant fall with 30 day interval. Potash contents, however, decrease with age except during 30 day interval when it shows a significant increase.

Effect of cutting treatments on yield

From Table II which gives the yield data and their statistical interpretation, it will be seen that there is an increase in yield with an increase in the interval between successive cuttings from 15 to 45 days. The increase, however, is' not uniform, for instance the increase in yield obtained from cutting at 30 day interval is very small compared with the increase resulting from cutting at 45 day interval. But there is no further increase in yield when the interval is increased from 45 to 60 days. This comparison can best be made by looking at the values of 'F'. The inference is that the active period of growth for berseem is between 30 and 45 days after cutting; the rate of growth before and after this period being much less.

The above results can briefly be summarized as below :

(i) With the shorter intervals between cuttings (15 or 30 days) the quality of the fodder is good, but the yield is very low.

(ii) Cuttings at intervals of 45 days give the highest total yield of fodder. The quality of fodder is inferior but the increase in yield compensates for loss in quality.

(iii) Cuttings at longer intervals (60 days) result in deterioration in quality with no advantage in quantity.

Effect of frequency of the yield of successive cuttings

In Table III are given the average yield of green herbage and of dry matter, per plot, of successive cuttings obtained throughout the life cycle of berseem under different cutting treatments.

TABLE III

Average yield of green herbage and dry matter in maunds per plot obtained in individual cuttings

No. of cutting	15 days' intervals		30 days' intervals		45 days' intervals		60 days' intervals	
	Green herbage	Dry matter	Green herbage	Dry matter	Green herbage	Dry matter	Green herbage	Dry matter
1	1.44	0.225	3.68	0.480	7.32	0.995	9.55	1.398
2	0.39	0.059	2.70	0.338	10.82	1.339	17.04	3.613
3	0.86	0.128	1.78	0.228	10.81	3.186	1.14	0.709
4	0.60	0.091	0.68	0.136	0.47	0.188		
5	0.30	0.051	0.12	0.047				
6	0.35	0.062						
7	0.35	0.062						
8	0.23	0.071						
9	0.05	0.020						

It will be observed that successive cuttings obtained at the intervals of 15 and 30 days show a significant fall in the yield. In the case of 45 days and 60 days, no such deterioration was noticed. In this case the low yield of the last cutting was due to the effect of hot and dry weather in May. This phenomenon has also been reported by Paterson [1933] and Wilsie *et al.* [1940] in the case of Napier grass (***Pennisetum Purpureum***) who state that greater frequency of cutting affects the vitality of the grass, retards the growth of the root system which results in a less virile stool. It appears that all these factors are also operative in the case of berseem. The low yields of berseem cut at shorter intervals can thus be explained as being due to the fact that its active period of growth lies between 30 and 45 days and more frequent cuttings affect the vigour of the plants adversely resulting in lower yields of subsequent cuttings.

Leaf/stem ratio

It is well-known that most of the plant food is stored in the leaves and the stems are comparatively poor in their nutritive value. By actual feeding trials with alfalfa leaves and stems, Sotola [1933] found that the percentage of digestible protein and total digestible nutrients in the case of stems were 4.17 and 41.55 respectively, while in the case of leaves they were 14.87 and 57.83. Thus besides the actual chemical analysis, the leaf/stem ratio should indicate the quality of the fodder. During the course of this investigation, leaves and stems of berseem under different cuttings were separated and analysed for various constituents.

The leaf/stem ratio and the results of chemical analysis of leaves and stems are given in Table IV.

TABLE IV

Chemical analysis of leaves and stems

Treatment	Leaf/stem ratio		Percentage of dry matter	Percentage on dry matter			
				Protein	CaO	P_2O_5	K_2O
15 days	2.17	Leaves	20.6	26.4	2.78	1.04	3.64
		Stems	10.4	12.6	2.05	0.58	4.52
30 days	1.08	Leaves	21.6	26.8	2.96	0.94	3.58
		Stems	8.6	12.0	2.20	0.46	5.16
45 days	0.55	Leaves	23.1	20.3	3.28	0.64	3.04
		Stems	16.8	10.8	2.09	0.36	3.54
60 days	0.48	Leaves	25.6	18.2	3.42	0.56	2.96
		Stems	17.8	10.0	2.00	0.34	3.26

It will be seen that longer intervals between cuttings decrease the ratio of leaves to stalks. Chemical analysis shows that leaves are richer in dry matter, protein, calcium and phosphorus than stalks while the latter were found to be richer in potash in case of all the cutting treatments. Protein and phosphorus contents of leaves and stems go on decreasing with age, but dry matter and calcium contents of leaves show a marked rise with age.

From the point of view of quality, it is, therefore, clear that the crop is more leafy if cut at shorter intervals and young leaves are richer in nutritive elements than the old ones ; these are factors which contribute to the superior quality of young growth.

SUMMARY

Results of an investigation into the effect of different intervals between the cuttings on the chemical composition and yield of berseem are reported.

The ash, protein and phosphorus contents of the fodder are found to decrease with increase in the cutting intervals but the fall between 15 and 30 days' intervals is smaller as compared to that with 45 days ; further fall from 45 to 60 days is negligible.

The moisture, calcium and potash contents show a marked rise from 15 to 30 days' intervals but they decrease when the interval is increased to 45 or 60 days.

From the yield point of view 45 days' intervals have been found to be most suitable.

The active period of growth of berseem has been found to lie between 30 and 45 days when most of the dry matter is formed.

A greater frequency in cutting adversely effects the growth and yield of successive cuttings.

Shorter intervals produce fodder with narrow leaf/stalk ratio and the chemical analysis of leaves and stalks shows that the leaves are richer in dry matter, protein, calcium and phosphorus than the stems. The younger leaves are richer in phosphorus, potash and protein than the older ones which, on the other hand, are richer in calcium.

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EFFECT OF MANURING ON THE *SCLEROTIAL* WILT OF *PAN* (*PIPER BETLE* L.)

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(Received for publication on 9 October 1945)

SEVERAL workers have advocated the use of organic and inorganic manures for the control of diseases caused by soil fungi. King and Loomis [1926] reported that heavy applications of manure or other organic materials consistently reduced the number of cotton plants dying from *Phymatotrichum* root rot. Streets [1934] reported experiments in which *Phymatotrichum* root rot on deciduous fruit and nut trees was controlled with anhydrous ammonia or ammonium sulphate. In a later publication he [Streets, 1937] recommended either ammonium sulphate or ammonium phosphate for this disease on a number of perennial crops. Jordan and others [1934] furnished further evidence of the effect of fertilizer treatments in reducing the loss of cotton from this fungus. Sardina and Landaluce [1934] claim that *Armillaria* root rot of the vine can be controlled only by preventive measures which in addition to extirpation, deep cultivation and drainage of the holes should include replacing of stable manure with well-balanced fertilizers. Walker and Musbach [1939] have obtained marked control of *Aphanomyces* root rot of peas under green house conditions with one application of 4-16-4 fertilizer at the rate of 500 lb. per acre. More recently Smith and Walker [1941] have produced evidence that the nitrogen fraction is more active in reducing of pea root rot than either the phosphorus or potash content when 2-12-6 fertilizer is used. In New Jersey, root rot of peas was reduced by heavy applications of hydrated lime (4000 lb. per acre) but lesser amounts had no inhibitory effect [Haenseler, 1927] and elsewhere, incidence of the rot was delayed and injurious effects on the host greatly reduced by use of 1000-2000 lb. of complete fertilizer per acre [Haenseler, 1931]. Greenhouse tests indicated that nitrate of soda, sulphate of ammonia and muriate of potash were more effective than superphosphate. Reinking [1942] in New York states that in favourable growing seasons, profitable yields of peas were obtained where soils were sufficiently fertilized (600 lb. per acre of a 5-20-5 or 10-20-10 fertilizer) inspite of the pathogenes in the soil. From Louisiana, Le Bean [1938] reports that nitrogenous fertilizers increased *Pythium* root rot of sugarcane, while high phosphate treatment reduced it. The same relationship of nitrate to *Pythium* root rot was also reported from Coimbatore by Ramakrishnan [1941] and from the United States of America by Rands and Dopp [1938]. The author [Chowdhury 1944, 1 & 2] has in his recent experiments found that oilcake and the different combinations of fertilizers have practically no influence on the incidence of *Phytophthora* foot rot and *Rhizoctonia* root rot diseases of *pan*.

Early results with *Sclerotium rolfsii* Sacc. were not encouraging for this line of attack. Edgerton and Tims [1936] reporting trials with 26 fertilizer combinations during two seasons in Louisiana found no clear cut differences between the various treatments. But Leach [1941] reported that the root rot of sugar beet due to *S. rolfsii* can be much reduced by the application of commercial fertilizers containing 100 lb. nitrogen per acre. More recently Leach and Davy [1942] reported consistent reduction in rot of sugar beets caused by *S. rolfsii* by the application of nitrogenous fertilizers. They found that on an average of all trials 50 lb of nitrogen per acre reduced infection by some 28 per cent, 100 lb. by 54 per cent and 200 lb. by 65 per cent. Encouraged by these results the author conducted certain field experiments to determine the possible application of similar methods for controlling *S. rolfsii* on *pan* under prevailing conditions. The results of these experiments are recorded in this paper.

Materials and methods

A piece of land where all the plants died of the disease was selected for the purpose. Examination showed that the field was with uniform infestation of *S. rolfsii*. An additional dose of infective material, however, was added to the soil by incorporating cultures of the fungus containing abundant sclerotia and mycelia into the soil.

The entire piece of land was then divided into 78 plots. Each plot was 15 ft. x 6 ft. There were 10 rows in each plot and 10 healthy *pan* setts were planted in each row. Planting was done in October, 1942.

The first manuring was done during the early part of April, 1943, and the subsequent manurings during the months of May, June, July, August, September and October, 1943.

During the year 1944, manuring was commenced in May and finished in October. Six applications were made, one application in each of the months May, June, July, August, September and October.

In every case the manuring was done on the same day and at the same time. The method of application was also the same. The oilcake was ground very fine, then spread along the ridges and afterwards covered with a thin layer of fine earth. The fertilizers, on the other hand, were mixed with equal quantities of fine earth, thoroughly mixed together and then applied along the ridges just like oilcake and then covered with a thin layer of soil.

The treatments were randomized and each treatment had six replications. The treatments were as follows:—

A.	*Control.*	No manure of any kind was applied.
B.	*Mustard oilcake.*	This was applied at the rate of 984 lb. per acre per year.
C.	*Mustard oilcake.*	This was applied at the rate of 1968 lb. per acre per year.
D.	*Mustard oilcake.*	This was applied at the rate of 3936 lb. per acre per year.
E.	*Ammonium sulphate.*	This was applied at the rate of 245 lb. per acre per year.
F.	*Ammonium sulphate.*	This was applied at the rate of 490 lb. per acre per year.
G.	*Ammonium sulphate.*	This was applied at the rate of 980 lb. per acre per year.
H.	*Sodium nitrate.*	This was applied at the rate of 320 lb. per acre per year.
I.	*Sodium nitrate.*	This was applied at the rate of 640 lb. per acre per year.
J.	*Sodium nitrate.*	This was applied at the rate of 1280 lb. per acre per year.
K.	*Ammonium phosphate.*	This was applied at the rate of 312 lb. per acre per year.
L.	*Ammonium phosphate.*	This was applied at the rate of 624 lb. per acre per year.
M.	*Ammonium phosphate.*	This was applied at the rate of 1248 lb. per acre per year.

Experimental results

The plots were kept under careful observation and deaths as they occurred were noted. The results obtained are recorded in Table I. The yield of leaves was also ascertained and is recorded in Table I. The dead plants were collected and examined; it was found that in all cases the deaths were due to the attack of the parasite *S. rolfsii*.

TABLE I

Effect of manuring on the sclerotial wilt of pan

Treatments	Fertilizer applied per acre in lb.	Nitrogen applied per acre in lb.	Average percentage of deaths		Average yield of leaves	
			1943	1944	1943	1944
Control ...	......	......	27.43	31.90	1752	1204
Mustard oilcake ...	984	50	9.19	7.36	3297	4957
Ammonium sulphate ...	245	50	9.23	7.20	3256	4962
Sodium nitrate ...	320	50	9.16	7.78	3285	4965
Ammonium phosphate ...	312	50	9.37	7.65	3292	4897
Mustard oilcake ...	1968	100	4.62	3.87	4980	6787
Ammonium sulphate ...	490	100	4.50	3.80	5021	6801
Sodium nitrate ...	640	100	4.36	3.72	4992	6792
Ammonium phosphate ...	624	100	4.45	3.85	5101	6800
Mustard oilcake ...	3936	200	2.65	2.01	7216	9456
Ammonium sulphate ...	980	200	2.30	1.87	7234	9621
Sodium nitrate ...	1280	200	2.51	1.90	7197	9572
Ammonium phosphate ...	1248	200	2.25	2.09	7209	9564

It will be observed from the data presented in Table I that the deaths were considerably less in the manured than in the control plots and the extent of death from the attack of the parasite was in proportion to the amount of nitrogen applied; the kind of the manure applied exerted little influence. Thus it will be seen that on an average the percentage of mortality in the plots receiving 50 lb., 100 lb. and 200 lb. of nitrogen per acre a year was 9.24, 3.48 and 2.42 respectively during the year 1943 and 7.49, 3.81 and 1.96 respectively during the year 1944. The different manures, oilcake, ammonium sulphate, sodium nitrate and ammonium phosphate were equally effctive in reducing the wilt. It will also be found that the yields of the leaves were also appreciably increased by these treatments. This was because of the lesser number of deaths and because of the stimulation of growth produced by the manures.

As to the general growth of the plants due to manuring it was found that the effects of the artificial fertilizers were earlier visible on the plants than oilcake, but in the long run no difference could be noticed between the plants given different manurial treatments; the height of the plants, the size and colour of the leaves and the general vigour of the plants were indistinguishable.

The plants in the control plots, on the other hand, were sickly, pale and stunted and the leaves much smaller in size and lesser in number.

SUMMARY

Applications of manures in field plots have consistently reduced the percentage of death of *pan* (*Piper betle*) plants due to the attack of *S. rolfsii*. Mustard oilcake, ammonium sulphate, sodium nitrate and ammonium phosphate proved equally effective and it was

found that the mortality from the attack of the parasite was in proportion to the amount of nitrogen applied, and the form of ntrogen applied exerted little influence. Yields were increased by these treatments both because of the lesser number of mortality and because of the stimulation of growth produced by the manures.

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EFFECT OF HYDROGEN-ION CONCENTRATION ON THE GROWTH AND PARASITISM OF *SCLEROTIUM ROLFSII* SACC.

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(With one text-figure)

Quite a large number of investigators have demonstrated that hydrogen-ion concentration influences the growth and parasitism of certain fungi and that some of the soil-borne diseases of plants could be wholly or partially controlled by altering the hydrogen-ion concentration of the soil. Garrett [1944] has recently furnished a tabulated list of the diseases that are favoured by acid and alkaline soils. Chupp [1928] and Wellman [1930] reported that the club-root disease of crucifers is favoured by acid soils and can be controlled by making the soil alkaline by the addition of lime. Doran [1927, 1928, 1929 and 1931] and Morgan and Anderson [1927] reported the reduction of *Thielaviopsis* black root rot of tobacco and *Phymatotrichum* cotton root rot by increasing soil acidity. Buchholts [1938] found that hydrogen-ion concentration below 6.5 favours root rot of sugar beets. Flor [1930] found that *Pythium* sp. responsible for root rot of sugarcane in Louisiana was capable of growing well from pH 5.6 to 9.2 and most of the cane soils were in the neighbourhood of the neutral mark. Marchel [1929] in Belgium reported that though black rot is present in acid soils it is rarely noticed when soil has

a reaction of *p*H 7 or greater. On the other hand, Grosshevoy [1931] reported that the heaviest damage from *Phoma* root rot occurred recently in very alkaline and neutral clay soils whereas the epidemic of 1926 took place under acid soil conditions.

Sclerotium rolfsii Sacc. is a soil inhabiting parasite and is known to cause serious damage to *pan* (*Piper betle* L.) in certain parts of Sylhet [Chowdhury, 1945]. A study was therefore made to determine how far the growth and parasitism of this organism are influenced by hydrogen-ion concentrations and whether it is possible to minimize or completely control its ravages by changing soil reactions. The results of this study are reported in this paper.

Mycelial growth

The range and optimum hydrogen-ion concentration for the growth of the organism were determined. Modified Richard's solution of Karrer and Web [1920] was used; 2.5 per cent agar was added. Petri dishes of equal sizes were used and an equal amount of the medium poured in each. The petri dishes were inoculated in triplicate and the linear rate of growth measured from day to day. The rate of growth noticed after five days is presented in Fig. 1.

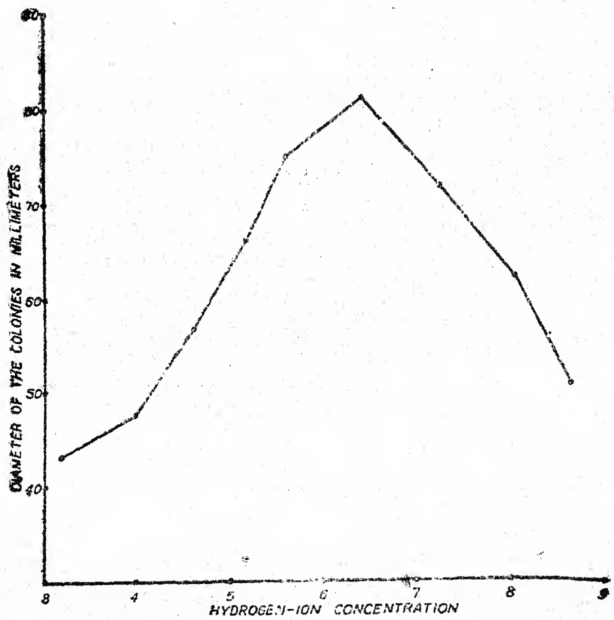

Fig. 1. Growth of *Sclerotium rolfsii* at different hydrogen-ion concentrations

It will be evident from the data presented in Fig. 1 that the fungus has a wide range of tolerance between *p*H 3.2 to 8.6. The optimum, however, lies at *p*H 6.4.

Formation of sclerotia

The formation of sclerotia at different hydrogen-ion concentrations was also studied. Beef-extract agar and Richard's solution agar were adjusted to different *p*H values and the fungus grown on them. The observations were made for 15 days; the results are recorded in Table I.

TABLE I

Effect of hydrogen-ion concentration on sclerotial formation

*p*H	Sclerotial formation		*p*H	Sclerotial formation	
	Beef-extract agar	Richard's agar		Beef-extract agar	Richard's agar
3.5	+	+	6.4	+++	+++
4.0	++	++	7.0	++	++
4.6	++	++	8.0	++	++
5.0	++	++	8.6	+	+

From the data presented in Table I it will be seen that sclerotial formation takes place over a wide range of hydrogen-ion concentration, 3.5 to 8.6 and that the optimum lies at *p*H 6.4.

MORTALITY AT DIFFERENT HYDROGEN-ION CONCENTRATIONS UNDER FIELD CONDITIONS

The hydrogen-ion concentrations of a large number of soil samples obtained from healthy and affected fields, collected from the different localities, were determined colorimetrically and were found to vary from 4.2 to 6.3, a range over which *S. rolfsii*, the fungus causing the sclerotial wilt of *pan*, also shows good growth. No appreciable differences in the *p*H values of the soils obtained from healthy and affected fields have, however, been noticed. All the same, an attempt was made to test the effect of changing soil reaction in an infected plot on the incidence of the disease. A piece of land where almost all the plants died of the disease and the fungus was found present in abundance was selected. The *p*H of the soil was determined and found to be 6. The reaction was changed by the addition of sulphur and lime to the soil and equal numbers of healthy cuttings were planted in each of the plots. The different treatments were randomized. Six replications of each treatment were made.

The data of this experiment showing the variations in soil reaction as a result of the addition of lime and sulphur and the average percentage of mortality of plants due to sclerotial wilt are recorded in Table II.

TABLE II

Incidence of the disease in relation to soil reaction

Treatments	Rate per acre in lb.	*p*H	Average percentage of deaths	
			1943	1944
Sulphur	4000	4.1	19.15	16.20
Sulphur	3000	5.4	20.91	17.92
Sulphur	2000	5.7	19.47	19.02
Untreated	......	6.0	19.75	18.78
Lime	2000	6.9	20.42	17.82
Lime	3000	7.6	21.26	16.10
Lime	4000	8.5	19.10	18.52

It will be evident from the data presented in Table II that the hydrogen-ion concentration of the field soil has practically no influence on the incidence of the disease, the average percentage of death being almost the same at all *p*H values. Thus it will appear that there exists no possibility of fighting the disease by altering soil reactions.

SUMMARY

Experiments were conducted to determine the effect of hydrogen-ion concentrations on the growth and parasitism of *S. rolfsii*. It was found that the fungus can grow over a wide range of *p*H and the optimum for growth and sclerotial formation lies at 6.4.

The hydrogen-ion concentration of a large number of soils obtained from healthy and affected fields was determined; no appreciable difference in the *p*H values of these soils could be noticed. The effect of changing soil reaction in an infected plot on the incidence of the disease was studied and it was found that there exists no correlation between the hydrogen-ion concentration of the soil and the incidence of the disease.

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EARLY BLIGHT OF POTATO IN INDIA*

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The causal organism of the early blight of potato was first described as a *Macrosporium* by Ellis and Martin [1882] from the dying leaves of potato near Newfield, New Jersey. The first reference to the fungus as a parasite and its association with potato leaf blight was made by Galloway [1891]. For some time there was much disagreement concerning the true cause of the disease. Some believed the *Macrosporium* only a secondary invader and disease primarily of non-parasitic origin, while others considered the fungus a parasite but not the cause of all the trouble. It was not until Jones [1895-96] published the results of further studies that the relation of *Macrosporium* to the various troubles was entirely cleared up. His field and laboratory studies led him to the final conclusion that the

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fungus (*Macrosporium*) was a true parasite and the primary cause of early blight. The fungus was first described as *Macrosporium* by Ellis and Martin [1882], but was assigned to *Alternaria* because of the discovery of Jones [1896] and Sorauer [1891] that the spores were sometimes formed in chains. Rands [1917] fully described early blight of potato and related plants. Since that time very little has been added to our knowledge of the early blight disease, but during the past decade many valuable data have accumulated bearing upon the control of the trouble by spraying

In India very little work has been done to investigate this disease thoroughly. McAlpine [1911] mentions that it is known in India, where, however, it does not seem to do much damage. Butler [1918] wrote "In India there is no indication at present of its becoming a dangerous pest, though I have on many occasions found it hastening the destruction wrought by *Phytophthora*". Owing to a serious outbreak of potato disease in Nilgiris, McRae, the then Mycologist to the Government of Madras was deputed to make an investigation of the same and advise as to its treatment. The extract of his report was published in the *Agric. J. India* [1911]. McRae mentioned that early blight was reported from the United Provinces in 1903, and for the first time from the Nilgiris in 1910. Ring blight was first reported by Capel [189-] from the Nilgiris. It also occurs in Bombay, Bengal and Mysore. Narasimhan [1935] reported from Mysore that potato fields in a locality where Rickets variety was planted was badly attacked by *Altearnaria* and the growers had sustained considerable loss. Fortunately, *Alternaria solani* is regarded as a weak parasite. It cannot gain a footing and produce much injury, unless the vitality of the plant is lowered. It is usually restricted only to the leaves, occasionally attacking the stem. In India, it is not reported from tubers either in the fields or in storage. In Germany, Belgium and England it can cause extensive damage to the tubers.

It is known that *A. solani* is the causal organism of early blight, but Bulter [1918] wrote that "A form with almost cubical spores (conidia) also occurs in England, but further work is necessary to establish its identity with true *A. solani*". The present author obtained infected plants (leaves) from Ootacamund and Simla, sent by the Imperial Economic Botanist, from Pusa collected by the Imperial Mycologist, and from Naini (Allahabad) sent by Dr Vestal of the Allahabad Agricultural Institute. Several isolations were made from the above material, out of which Simla material only gave typical obclavate, long, beaked spores of *A. solani*, while, from the rest, the author repeatedly got only very small spores without a beak and with longitudinal septa, sporas often being in chains in cultures. This work was undertaken on suggestion of Dr Padwick to ascertain the association of small spored *Alternaria* causing early blight (or leaf-spot) on potato in India.

Symptoms and isolations

(1) *Simla material.* The infected leaves showed typical *Alternaria* spots. They were scattered all over the leaf, roughly circular to elliptic, concentrically zonate, and brown in colour. There were no spores on the spots. The infected leaf, after sterilization, was put in a moist chamber and sterilized bits were transferred aseptically on slants of two and four per cent potato dextrose agar and oatmeal agar, but the fungus did not sporulate either in the moist chamber or on media slants kept at different temperatures. To procure spores the method described by Rands [1917,b] was adopted. Fifteen to twenty-day old cultures in petri dishes were shredded and mycelium severely wounded. The utmost care was taken to avoid contamination. The shredded bits were separated and allowed to dry partially by removing the lid of the petri dish, and exposing to sunlight in a sterilized moist chamber. Within two to three days a few spores were produced. These spores were measured and their morphological characters were recorded. Single spore tubes were prepared on oatmel agar for further studies.

(2) *Ootacamund material.* The same symptoms on leaves as in case of the Simla material, except that the spots were dark-brown to black and the concentric zones in the spots were very indistinct. No spores were formed on the spots. Abundant supply of spores was obtained both in moist chamber and in oatmeal agar slants. Single spore cultures were prepared on oatmeal agar.

(3) ***Naini (Allahabad) material.*** Leaves had very irregular black spots without any concentric zones. ***Alternaria, Acrothecium*** and ***Helminthosporium*** were found on the surface of the leaf. Infected portions produced very abundant spores both in the moist chambers and oatmeal slants. Single spore cultures were prepared for studies on oatmeal agar.

(4) ***Pusa material.*** Leaves had very little infection. Spots were small, irregular in form, and of light-brown colour. No spores were found on infected patches. Moderate numbers of spores were produced in a moist chamber and on oatmeal agar slants. Single spore cultures were prepared for further studies.

Only the Simla strain, which produced a few spores on wounding, showed typical, long, obclavate, beaked and muriform spores of *A. solani*. The strains isolated from material obtained from Ootacamund, Naini and Pusa, produced small longitudinally septate, short spores, without a beak.

Morphology of the fungus

Cultures of the fungus were prepared on oatmeal agar for use in inoculating the agar slants and perti-dishes of two per cent potato-dextrose agar, oatmeal agar, and tubes of soaked rice which were steamed three times in order to ensure complete sterilization. When the cultures had grown sufficiently, transfers were made of small portions of agar and mycelium to the media in petri-dishes and slants. Duplicate tubes and petri-dishes were prepared. Inoculated tubes and petri-dishes were kept at room temperature, the temperature of the underground room being almost constant, varying from 19 to 20.5 degrees. Morphological characters, change in colour of the media, and measurement of spores were noted after 21 days. Spores were measured and their form and septation recorded from two per cent potato-dextrose and oatmeal agar. The same observations were recorded after 30 days, but no change had occurred since the twenty-first day. If we closely study Table I, it is evident that the aerial mycelium is moderate in amount in Ootacamund and Allahabad strains, while it is nil in Pusa strain on oatmeal agar. It is almost the same in amount on two per cent potato-dextrose, while on steamed rice in strains

TABLE I

Cultural characters of Alternaria ***spp. from potato on different media***

Medium	Fungus	Aerial mycelium		Change in colour of the medium
		Amount	Colour	
Oatmeal agar	Ootacamund	Moderate	Dark olive	No change
,,	Naini	,,	Dark olive gray	,,
,,	Pusa	Nil	...	,,
,,	Simla	Moderate	Olive gray to dark olive gray	Cream buff to chamois
Two per cent potato-dextrose agar	Ootacamund	Moderate	Dark olive	No change
,,	Naini	Good	Dirty-white to pale olive gray	,,
,,	Pusa	Nil	...	,,
,,	Simla	Moderate	Pale brownish drab with scattered small patches of pink	Victoria lake
Steamed rice	Ootacamund	Good	Pale smoke gray	Light grayish vinaceous
,,	Naini	Nil	...	Same as in Ootacamund but very little and change being extremely slow
,,	Pusa	Good	Light olive gray	Fawn to army brown
,,	Simla	Very little	Dark olive gray	Cream-buff to chamois

from Ootacamund and Naini the amount is considerable. In the amount of aerial mycelium and general colour, the strains from Ootacamund. Naini and Pusa closely agree. All these three strains produce no change in colour of the media with oatmeal agar and two per cent potato-dextrose agar, but on steamed-rice they form some colour. On steamed-rice, strains from Ootacamund and Pusa show appreciable amounts of colour, but Naini strain is less chromogenic than the former two, and it is slow in developing colour. In short, in amount and colour of aerial mycelium. all the three closely resembled one another and they are entirely non-chromogenic on oatmeal agar and two per cent potato-dextrose agar, and partially chromogenic on steamed-rice. Measurements of the spores, and their septation, recorded in Table II, clearly reveal that all these three strains are morphologically similar.

The Simla strain differs much from those of Ootacamund, Naini and Pusa, being long-sported and highly chromogenic. It shows a moderate to good amount of aerial mycelium on oatmeal and potato-dextrose agar, the mycelium being olive gray on oatmeal agar and potato-dextrose; while on steamed rice, it develops very little olive gray mycelium. It is highly chromogenic on all the three media.

Table II

Measurements of the spores and their separation

Strain	Dimensions (excluding beak)	Average dimensions of beak	No. of transverse septa	No. of longitudinal septa	Colour of spores
Ootacamund	25 x 12 (11-52 x 8-19)	Lacking	0—6	0—3	Buffy olive
Naini	23 x 12 (8-41 x 9-15)	Lacking	0—5	0—3	Saccardo's olive
Pusa	24 x 11 (11-45 x 8-15)	Lacking	0—6	0—3	Brownish olive
Simla	140 x 18 (105-194 x 13-22)	42 x 4	4—19	0—4	Dark olive with beak of lighter colour

Average dimensions, septation, colour, etc., are shown in Table II. It is seen that the spores of Ootacamund, Naini and Pusa strains agree in their dimensions, septation, colour and abundance. Spores of the Simla isolation are long, obclavate, olivaceous, very variable in shape, terminating in a very long and bright coloured or partly hyaline septate beak, the latter being frequently branched. Conidia were not observed in chains in Simla strains, but chains of 3 to 6 spores were seen in cultures of Ootacamund, Naini and Pusa strains, on all the three media used for the study.

Pathogenicity

Tubers of potatoes from Simla were planted in pots and three plants were inoculated with each strain at the age of two and a half months. Each inoculated plant was placed under a bell jar, and sprayed with sterilized water twice daily for three days. Uninoculated plants were similarly placed under bell jars and sprayed daily to serve as controls.

The following inoculation methods were used :

(1) A drop of sterilized water containing a large number of spores was placed on a leaf, which was partially covered with a small piece of cotton wool soaked in a similar spore suspension. The method was used for all except the Simla strain, which formed too few spores.

(2) Leaves were sprayed with a spore suspension, and kept moist with a fine spray of water for 72 hours. This method was not used for the Simla strain.

(3) Leaves were washed with distilled water. Small punctures were made with a steel needle on the surface of the leaflets and stems. A small piece of potato-dextrose agar with abundant mycelium was placed on the area punctured with the needle. Moist cotton wool was kept for 48 hours on the agar. The plants were sprayed with water for 72 hours.

The method was used only for the Simla strain.

These were intended as preliminary experiments only and the results are, therefore, given briefly as follows :

Ootacamund strain

Method 1.—Out of 20 inoculations made, only one small irregularly shaped discoloured patch was formed. The fungus was reisolated.

Method 2.—Numerous pin-head sized spots appeared, which did not enlarge. From 20 small infected pieces, the fungus was reisolated in four cases.

Naini strain

Method 1.—Results identical with Ootacamund strain.

Method 2.—Symptoms as in Ootacamund strain. From 30 infected pieces, the fungus was reisolated in three cases.

Pusa strain

Method 1.—A number of spots were formed, larger than with the Ootacamund and Naini strains, light brown, irregular in shape. From six infected pieces, the fungus was isolated in one case only.

Method 2.—Failed to take infection.

Simla strain

Method 3.—Numerous large patches formed on the leaves, which increased in size as the leaves withered. Concentric rings were not formed. From ten infected pieces, the fungus was reisolated in six cases.

These tests were conducted in March, when the temperature in Delhi is abnormally high for growing potatoes, and at a time when the disease does not usually appear. The method of inoculation, in the case of the Pusa strain, was different from, and more severe than, that used with the other strains. That the Simla strain is highly pathogenic on injured plants is clear. Infection clearly took place with the other strains, but was much less severe, due possibly to the fact that the plants were not injured, possibly to the high temperatures prevailing.

Discussion

Cooke [1905] described the leaf-curl of potato, due to *M. solani* (Cooke). Afterwards it was discovered by Saccardo that a species had already been named *M. solani*, wherefore, he called the present species *Macrosporium Cookii*, and it became known as a virulent parasite. The measurement and other characters of the small-spored *Alternaria* isolated from Ooty, Naini and Pusa materials do not agree with *M. Cookii* (Saccardo).

Elliot [1911] fully described the taxonomic characters of the genera *Alternaria* and *Macrosporium*. According to him, all obclavate, ovate, cuneate, or elongated pointed spores of the *Macrosporium-Alternaria* type form chains and belong to *Alternaria*. The small-spored strains which occasionally formed chains in culture, and the formation of characteristic *Alternaria* spots on the host, clearly indicate that they all belong to the genus *Alternaria*. Incomplete descriptions, mutations, secondary development of spores, dwarfing of spores in cultures, and facultative parasitism resulting on large host ranges, have created great confusion in the classification of species of *Alternaria*. Elliot [1911] placed the species of

Alternaria in seven main morphological groups, and he stressed the point that echinulation is not a constant character. He showed that generic name *Macrosporium* should be abandoned, because all the species of *Macrosporium* belong to *Alternaria* or *Stemphylium*, having catenulate, sarcinae form, or globose conidia.

Young [1929] collected the literature on *Alternaria* and *Macrosporium* and tabulated the measurements of the spores of *Alternaria* and *Macrosporium* on different host genera of *Solanaceae*. He arranged the species in the table on the basis of minimum spore lengths. The measurements of the small-spored *Alternaria* mentioned in this paper do not agree with his measurements of *Alternaria* spp. on the genus *Solanum*. However, they agree with his measurements of *Alternaria* on the genus *Lycopersicum*, namely 14.60 x 7.20 and 14.56 x 11-14, the dimensions of the strains from Ootacamund, Naini and Pusa being 24 x 12, 23 x 12 and 24 x 11 respectively. This indicates that the small-spored *Alternaria* resembles the one on *Lycopersicum*. It somewhat resembles *A. tomato* Cooke in the amount of sporulation, colour, mode of septation and measurement of spores. A culture of *A. solani* Cooke was obtained from Baarn, but failed to form spores.

It seems possible, but is by no means certain, that the small-spored *Alternaria* isolated from potato leaves from Ootacamund, Naini and Pusa may be *A. tomato* Cooke.

To come to a definite conclusion, it is essential to try again the pathogenicity tests on potato, and also with Ootacamund, Naini and Pusa strains on young tomato plants.

Summary

(1) Isolations were made from diseased patches on potato leaves, obtained from Ootacamund, Naini, Pusa and Simla, suffering from "early blight."

(2) *Alternaria* isolates from Ootacamund, Naini and Pusa closely resemble each other in their form, colour and cultural characters. They are non-chromogenic on oatmeal and two per cent potato dextrose agar, but partially chromogenic on steamed rice. The Simla strain formed a small number of spores which were long, beaked, obclavate and typical *A. solani* spores; cultures of this strain were chromogenic.

(3) Symptoms on the host and pathogenicity tests indicate that Simla strain is highly pathogenic, while Ootacamund, Naini and Pusa strains are weak parasites.

(4) In India "Early blight" of potato is not only due to *A. solani* but it is also due to a small-spored, abundantly to moderately sporing, and partially chromogenic species, possibly *A. tomato* Cooke.

(5) Further pathogenicity tests on potato and tomato plants are suggested.

Acknowledgement

I take the opportunity to express my thanks and deep feelings of appreciation to Dr G. Watts Padwick, Imperial Mycologist, Imperial Agricultural Research Institute, New Delhi, for suggesting the problem and guiding the work and for many helpful suggestions.

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A PRELIMINARY NOTE ON THE ESSENTIAL OIL BEARING PLANTS GROWING IN KASHMIR

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(Received for publication on 7 February 1946)

CONSIDERABLE quantities of essential oils are in demand in India for medicinal and cosmetic purposes and most of these are at present imported into India. It has been observed that a large number of essential-oil bearing plants grow in a state of nature in Kashmir and the experimental cultivation of most of the exotics has been successful in the forest nurseries.

A preliminary investigation of these plants was undertaken to ascertain whether the oils obtained from these could be successfully exploited for the above purposes. The percentage yield of the oil from the plant was ascertained and the specific gravity and refractive index of the oils obtained was tested. Detailed investigation of the essential oils obtained from some of these plants is in hand and will be communicated in due course. The plants named below were studied.

Mentha sylvestris (VERN. *Jangli Pudina*)

It is very common in Kashmir growing wild on the sides of water streams and other damp localities. The plant is often used in indigenous medicine as a carminative, anti-septic and stimulant. The dried leaves and flowering tops of the plant were steam-distilled and a pale yellow oil with a minty odour was obtained. The results of analysis of the oil are given in Table I along with those of the Cyprus oil [Gildemeister and Hoffmann, 1922.]

TABLE I

Results of anaylsis of the oil of Mentha sylvestris

	Local oil	Cyprus oil
Yield of the oil	1.2 per cent	0.9 per cent
Specific gravity	0.985 at 15° C.	0.9852 at 15°C.
Refractive index	1.471 at 20° C.	1.4685 at 20°C.
Ester value	65.8	20.9

Mentha arvensis (VERN. *Pudina*)

The plant is found wild in the Kashmir valley at an altitude of 5,000 to 10,000 ft. and is very common near Gulmarg. It is used locally as a stimulant and carminative. The dried leaves and flowering tops on steam distillation gave a pale brown essential oil, the properties of which are compared in Table II with the properties of Japanese natural and dementholished oil [Parry, 1921].

TABLE II

Properties of the essential oil of Mentha arvensis

	Local oil	Japanese natural oil	Dementholised oil
Yield of the oil	0.45 per cent	1.07 to 1.6 per cent	1.07 to 1.6 per cent
Specific Gravity	0.9161 at 15° C.	0.90 to 0.912 at 15° C.	0.894 to 0.906 at 15° C.
Refractive index	1.474 at 20° C.	1.4600 to 1.4635 at 20° C.	1.459 to 1.465 at 20°C.

On allowing the oil to stand at 0°C., no crystals of menthol separated.

Mentha piperita

The plant is not indigenous in India. Some rooted suckers of the plants were obtained from the Punjab Agriculture College, Lyallpur, for trial cultivation. The suckers were transplanted successfully in the drug nursery of the Forest Department at Baramulla. The dried flowering tops and leaves of the plant were steam distilled and 0.71 per cent of essential oil was recovered.

In England the yield of the oil from the dry herb varies from 0.5 to 1.0 per cent and in Russia a yield from 1.6 to 1.7 per cent from the dried leaves is the average [Parry 1921].

As the quantity of the sample obtained was small, sufficient oil could not be obtained for studying its properties.

Mentha pulegium (Pennyroyal)

Pennyroyal oil is used in considerable quantities in perfumery and soap making. The plant is not indigenous to Kashmir but has been successfully cultivated at the forest nursery Baramulla. The principal constituent of the pennyroyal oil is a ketone called pulgone. This can be changed to menthone and then to menthol which has a great demand in India. The dried leaves and flowering tops of the plant were steam-distilled and the properties of the oil obtained are compared in Table III with those of the Mediterranean Pennyroyal oil [Gildemeister and Hoffmann, 1922].

TABLE III

The properties of the oil of Mentha pulegium

	Local oil	Mediterranean oil
Yield of the oil	2.3 per cent	—
Specific gravity	0.8925 at 15° C.	0.93 to 0.95 at 15°C.
Refractive index	1.483 at 20°C.	1.483 to 1.486 at 20°C.

Inula racemosa (VERN. *Poshkar*)

It is a moisture loving plant, grows on elevations ascending from 7,000 to 9,000 ft. and is common in Gurez and Gulmarg. The roots are used in indigenous medicines for their expectorant, diaphoretic and emmenagogue properties. They possess a mild aromatic odour and are sometimes used to adulterate ***Sausurea lappa*** (*Kuth*) which brings a higher price in the market. It is collected early in autumn when the seeds mature. On steam-distilling the dry roots gave 0.38 per cent of essential oil which solidified on standing. Further properties, i. e. specific gravity and refractive index, are being studied.

Lavanduta officinalis

Quite a large amount of lavender oil is used in India in perfumery and soap-making and the whole of this is imported from foreign countries.

The seedlings of this plant were imported and experimental cultivation was started at the drug nursery of the Forest Department. The dry flowers were steam-distilled and the results of analysis of the oil obtained recorded. For comparison the properties of the English oil [Gildemeister and Hoffmann, 1922; British Pharmacopoeial Codex, 1934] are also given in Table IV.

TABLE IV

Properties of the oil of Lavendula officinalis

	Local oil	English oil
Yield of the oil	2.4 per cent (of the dry flowers)	0.8 to 1.7 per cent (of the fresh flowers)
Specific gravity	0.9192 at 15°C.	0.882 to 0.90 at 15°C. (foreign oil 0.883 to 0.895 at 15°C.)
Percentage of ester	24.8 per cent	7 to 14 per cent (foreign oil not less than 35 per cent)

Srimmia laureola

This plant is found in abundance as a undergrowth shrub in fir forests at an altitude of 7,000 to 9,000 ft. It is very common in Gulmarg and Pahalgam. The leaves are often used locally as an incense and in small-pox [Kaul, 1928]. The fresh leaves on steam distillation gave a light oil with the properties given in Table V.

TABLE V

Properties of the oil of Skimmia laureola

Yield of the oil	0.49 per cent
Specific gravity	0.8058 at 15° C.
Refractive index	1.4784 at 20°C.

The oil has been found to contain quite a large percentage of linalyl acetate which is the main constituent of the lavender oil. *Skimmia* oil, therefore, stands a good chance of its being employed in perfumery and soap-making in place of lavender oil.

Thymus serphyllum (VERN. *Ban-ajwain*)

The plant grows wild throughout the Kashmir valley and is used in *Unani* and *Ayurvedic* systems for complaints in stomach and liver and as a remedy for toothaches. The whole dried plant on steam-distillation gave a pale yellow oil. In Table VI are given the properties of the local oil along with those of the European oil [Gildemeister and Hoffmann, 1922]

TABLE VI

Properties of the oil of Thymus serphyllum

	Local oil	European oil
Yield of the oil	0.72 per cent	0.15 to 0.6 per cent
Specific gravity	0.9404 at 15° C.	0.890 to 0.92 at 15°C.
Refractive index	1.5110 at 20° C.	

Saussurea lappa (VERN. *Kuth*)

It is a herbaceous plant growing wild in Kashmir forests. It grows in shady moist places especially under birch trees and dwarf willows. The chief places where it grows abundantly in Kashmir are the Kishenganga valley and the higher elevations of the Chenab valley. It is also found in Reasi, Ramban and Udhampur divisions. The roots are collected in autumn months before snowfall. They are mostly used as stimulant, in cough, asthama, fever, dyspepsia and skin diseases. It is locally employed

as a preservative for woollen goods. Large quantities of this are annually exported to China where it is burnt as an incense in Pagodas [Kaul, 1928].

The dry roots were steam-distilled and a pale brown oil with characteristics as shown in Table VII is obtained.

TABLE VII

Characteristics of the oil of Sausurea lappa

Yield of the oil	1.22 per cent
Specific gravity	0.9099 at 15°C.
Refractive index	1.522 at 20°C.

Nepeta ciliaris (VERN. *Zufa*)

There are a number of species of *Nepeta* which grow wild in Kashmir. These species are ***Nepeta ciliaris, N. ruderalis*** and ***N. elliptica*** and all are used medicinally here.

Nepeta ciliaris commonly grows at altitude between 6,000 to 7,000 ft. and a ***sharbet*** (syrup) made from leaves and seeds is given in coughs and fevers. The dried leaves and flowering tops were steam-distilled with results as shown in Table VIII.

TABLE VIII

Characteristics of the oil of Nepeta ciliaris

Yield of the oil	0.543 pe cent
Specific gravity	1.061 at 20°C.
Refractive index	1.499 at 20°C.

Nepeta ruderalis

It grows in Kashmir on the road side and is used in the treatment of fever and gonorrheoea. The dried leaves and flowering tops were steam-distilled but only traces of oil were obtained.

The dried roots of ***Iris kumaoneneis*** (vern. *Krisham*) and ***Iris kashmiriana*** growing wild in Kashmir and reputed for their aromatic properties were also steam-distilled but only traces of the essential oil were obtained.

The dried bark of *Betula utilis* (vern. *Bhojpattra*) and the dried leaves and flowering tops of *Plectranthus regosus* (vern. *Pumar*) which also grow wild and are reputed for their aromatic properties gave on steam-distillation only traces of oil.

ACKNOWLEDGEMENT

We are grateful to Col. Sir Ram Nath Chopra for his valuable advice in the course of this investigation.

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PLANT QUARANTINE NOTIFICATION

Notification No. F. 16-5/44-A. dated the 3rd December 1945 of the Government of India in the Department of Agriculture.

In exercise of the powers conferred by Sub-section (1) of Section 3 of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to direct that the following further amendment shall be made in the order published with the notification of the Government of India in the late Department of Education, Health and Lands, No. F. 320/35-A., dated the 20th July 1936, namely :

In sub-paragraph (1) of paragraph 14 of the said order, for the words 'Kathiawar port' the words 'port of Kathiawar, or of the Lasbela or Kalat State' shall be substituted.

THE MAYNARD GANGA RAM PRIZE

APPLICATIONS are invited for the award of the Maynard Ganga Ram Prize of Rs. 3,000 for a discovery or an invention or a new practical method which will tend to increase agricultural production in the Punjab on paying basis. The prize is open to all, irrespective of caste, creed or nationality and Government servants are also eligible for it. Essays and theses are not accepted. The prize will be awarded for something practically achieved as a result of work done after the prize was founded in 1925. Competitors in their applications must give a clear account of the history of their invention or discovery and must produce clear evidence that it is the result of their own work. In the case of an improved crop details of parentage, evolution and history and a botanical description are necessary.

The Managing Committee reserves to itself the right of withholding or postponing the prize if no satisfactory achievement is reported to it, or to reduce the amount of the prize or to divide it if the quality of the entries justify this decision.

Entries should reach the Director of Agriculture, Punjab, Lahore, not later than 31st October, 1946.

ORIGINAL ARTICLES

COMPARATIVE STUDIES ON INDIAN SOILS

VI. THE DEPTH DISTRIBUTION OF WATER-SOLUBLE SALTS IN THE PROFILE

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(Received for publication on 21 March 1944)

ONE of the chief agencies in the differentiation of the materials within a soil horizon is the soil solution. A study of the nature of the soil solution, therefore, would yield valuable information about the soil forming processes. Zakharov [1906] discussed the significance of the soil solution for the different processes of soil formation and established its characteristic properties for the various soil types. Though soil extracts prepared in the laboratories could never correspond to soil solutions existing under natural condition, Sigmond [1938] found that water extracts might be very instructive in the chemical characterization of a soil.

Generation of soluble salts in a soil depends mainly upon the parent material. It is, however, largely affected by the climate-vegetation complex. The dependency of the composition of soluble salts on the parent material may sometimes be masked by the effect of climate which leaves its impress upon the concentration rather than the composition of the salts. Arid regions are always characterized by higher soluble salt content than the humid regions. This is rather unexpected as with more rainfall more soluble salts are expected to form in the soil. McCool and Millar [1920] working with soils from widely different climatic regions, found that amounts of salts generated by washed arid region soils were actually smaller than those from soils of humid regions. With low rainfall and high temperature salts try to accumulate at the surface layers of arid region soils while they go down in humid soils with higher rainfall. The resultant effect is the high concentration of soluble salts in arid regions and much less soluble salt content of the soils of humid or perhumid regions. Thus effect of climate on a soil is more easily reflected on the soluble salt content than on any other factor. Distribution of the salts along the profile is thus expected to be uneven depending on the nature of the horizon and its depth from the surface. Depth distribution of water soluble salts in the profile is, therefore, of importance in assessing the effect of climate on soils.

Materials and methods of analysis

Soils reported in the paper were all virgin, collected from different parts of India for the purpose of a preliminary soil survey.*

In estimating the soluble salt content of a soil, the ratio of soil to water is an important consideration. Soil water ratio does not affect the solubility of chloride and nitrate ions but it is an important factor in regard to carbonate and bicarbonate ions, besides the effect of soil water ratio on the relative proportions of cations and anions due to base exchange. In our determinations the widely adopted ratio of one of soil to five of water was adopted.

Extraction of soluble salts. One hundred grams of soil were treated with 500 c.c. carbon dioxide-free distilled water and left for 24 hours with frequent shakings. The soil water suspension was then filtered through Pasteur Chamberland Filter.

Total salts, calcium and magnesium. One hundred cubic centimetres of the extract was taken in a weighed platinum basin and evaporated on water bath till dry. It was then dried in an air oven kept at 105°C. and cooled in a desiccator and weighed to a constant weight. The residue was total solids.

The residue after the determination of total solids was ignited and redissolved with dilute HCl. The solution was treated with excess ammonia and after acidifying the liquid with a few drops of acetic acid calcium was precipitated as oxalate by boiling with 1 gm. of ammonium oxalate. Calcium was estimated from the precipitate in the usual way.

*Descriptions of soils are given in part I of this series=*Indian J. agric. sci.* **14**, 333-44

The filtrate and washings from above were concentrated, ammonified and treated with sodium phosphate. It was left for 24 hours. The precipitate of magnesium ammonium phosphate was washed, dried and ignited to magnesium pyrophosphate and weighed.

Carbonate, bicarbonate and chloride. Another 100 c.c. aliquot was taken and titrated with N/50 H_2SO_4 with phenolpthalein as indicator. Methyl orange was then added and titration was continued for bicarbonate. After neutralization, chloride was estimated by titration with N/50 $AgNO_3$ with $K_2C_rO_4$ indicator.

Sulphate. Sulphate was weighed as $BaSO_4$ after precipitation from an acidified 100 c.c. aliquot by boiling with $BaCl_2$.

Potassium. Another 100 c.c. aliquot was evaporated to dryness, treated with HCl and 1 c.c. of H_2PtCl_6. The residue was washed and weighed as K_2PtCl_6.

Sodium. Sodium was obtained by difference. The acids and available bases were combined to form salts after the method of combination followed by Leather [1902]. Excess acid was assumed to be combined with sodium.

Nitrate. Forty grams of soil were shaken with 200 c.c. of water with 1 gm. of $CaSO_4$ to aid filtration and filtered through an ordinary filter paper. An aliquot was evaporated on a porcelain basin on a water bath and the nitrate was determined by the phenol disulphonic acid method. Chlorides, when present in large amounts, were removed by silver sulphate.

Classification of Indian soils on the basis of soluble salts

The results of analysis are given in the appendix as percentages on air-dry soil.

The analyses of aqueous extracts of the soils of the profiles have given useful indications regarding anions and cations which play an important role in the soil solution. Striking differences which indicate water and salt movement under climatic influences, have been noticed. On the basis of the nature and concentration of water soluble salts at different depths five main groups may be formed. In the profiles of the first group sodium and chlorine predominate; in the second the sulphate radical is either very low or absent; the third group is characterized by the predominance of either Ca or Na or SO_3 or Cl; the fourth is characterized by very high salt content, while the fifth contains very low amount of salts.

On the basis of relative concentrations also, five main groups may be differentiated. Thus there are (i) profiles in which the concentration of soluble salts is highest at the surface and lowest at the bottom; (ii) profiles in which the concentration is highest at the surface but lowest somewhere in the middle of them; (iii) profiles in which the concentration is highest somewhere in the middle, but lowest either at the surface or at the bottom; (iv) profiles in which the concentration is highest at the bottom, and lowest either at the surface or somewhere in the middle; and (v) profiles in which the concentration of water-soluble salts is more or less uniform throughout and the total quantities of them are also very low.

Group (iv) can be further subdivided into two groups (*a*) one in which the total quantity of water-soluble salts is very low, and the difference between the highest and the lowest is not considerable; and (*b*) the other in which the total quantity of water-soluble salts is very high, and the difference between the highest and the lowest is also very great.

Peshawar, Mianwali and Taliparamba come under the first group. In Peshawar profile sodium chloride has concentrated itself into the first two feet from the surface, there being practically nothing of it below this depth. Calcium and magnesium are proportional to total soluble salts in all the depths. The significant point of difference between this profile and the other two profiles (Mianwali and Taliparamba) of this group is that sodium chloride, which concentrated itself into the first two feet of the former, was distributed throughout in the latter.

The second group comprise Gurdaspur, Jorhat, Rangpur, Ranchi, Karachi and Nagpur. The amount of total salts in these profiles, with the exception of Karachi, is not high. Chloride, the preponderating radical, is proportional to the total soluble salts. Sulphate is low and is not present in all the profiles. There is no nitrate in any of them. Karachi, however, is much richer in soluble salts than other profiles of the group and contains nitrate and enough of sulphate. Its composition shows closer proximity to group III. Chloride is not proportional to total soluble salts in this profile.

Lahore, Lyallpur, Kangra, Padrauna, Makrera, Chinsura, Sylhet, Haripur-Hazara, Tabiji, Koilpatti, Karimganj, Hagari, Samalkot and Mirpurkhas fall into the third group. They are mostly rich in calcium and sodium. Some of them are rich in sulphate, and some in chloride. Those rich in sulphate are found to contain nitrate also, whereas those rich in chloride do not generally contain any nitrate. Chlorine is proportional to the total soluble salts in most of the cases. In Hagari and Samalkot, sodium is the preponderating base and in Mirpurkhas potassium. Padrauna and Mirpurkhas deviate slightly from the other profiles of the group in as much as the lowest concentration of salts in them is in the middle instead of being either in the surface or at the bottom.

Group (iv, a) consists of Akola, Labhandi, Waraseoni, Coimbatore, Nandyal, Anakapalle and Berhampur. Sodium bicarbonate is the principal salt in Akola, Labhandi and Nandyal and calcium bicarbonate in Waraseoni and Coimbatore. Nandyal is richer also in sodium sulphate and sodium chloride. The composition of Anakapalle and Berhampur profiles bear resemblance to that of group (iv). Anakapalle is rich in calcium bicarbonate and sodium chloride, whereas Berhampur is rich in potassium bicarbonate and sodium chloride. There is no nitrate in any of them except Nandyal which contains some in the first two feet only.

Group (iv, b) consists of Sakrand and Padegaon. They are the richest of all as far as soluble salts are concerned, so much so that the amount of salts at their lowest depth (5 ft.) are enough to make a soil sterile. In the case of Sakrand, the quantities of sodium and chlorine fall at 5 ft., although there is a definite increase in the total soluble salts. This is not the case with Padegaon. All other radicals, except HCO_3 which has fallen towards the end in both the profiles, have followed more or less the course of total soluble salts.

Shahjahanpur, Powerkhera, Indore, Sirsi, Surat, Chandkhuri, Kheri-Adhartal, Kharua, Dacca, Pusa and Delhi come under group V. These are found to contain mostly calcium bicarbonate, Sirsi being perhaps the only exception. There is no nitrate in any of them except Pusa. They are the poorest of all in total soluble salts.

The principal salt in Chandkhuri, Kheri-Adhartal, Kharua and Dacca is either calcium bicarbonate or sodium chloride.

Summary

On the basis of the nature and concentration of soluble salts at different depths, Indian soils may be classified into five main groups.

Group I. The group is characterized by the predominance of Na and Cl. The concentration of soluble salts in such a profile is highest at the surface and lowest at the bottom.

Group II. Sulphate is very low; soluble salts are highest at the top, not lowest at the bottom.

Group III. It is characterized by predominance of either Ca or Na or SO_3 or Cl; concentration of salts is highest neither at the surface nor at the bottom.

Group IV. This group is generally characterized by very high salt content, the concentration being highest at the bottom.

Group V. This group is characterized by low content of soluble salts which are distributed more or less evenly throughout the profile.

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APPENDIX

The water-soluble salt contents of soil profiles

Depth in ft.	$Ca(NO_3)_2$	$CaCO_3$	$Ca(HCO_3)_2$	$CaSO_4$	$CaCl_2$	$Mg(HCO_3)_2$	$MgSO_4$	$MgCl_2$	$KHCO_3$	K_2SO_4	KCl	$NaHCO_3$	Na_2SO_4	NaCl	Total solids
						1. *Peshawar*									
0—1	..	0·0054	0·0601	..	..	0·0110	0·0288	..	..	0·0144	..	..	0·0076	0·0351	0·175
1—2	..	..	0·0405	0·0135	..	..	0·0293	0·0003	..	..	0·0046	..	..	0·0369	0·145
2—3	..	..	0·0344	..	..	0·0056	0·0065	0·0127	..	..	0·0025	..	..	..	0·070
3—4	..	..	0·0324	..	..	0·0048	0·0052	0·0142	..	..	..	..	..	..	0·060
4—5	..	..	0·0243	..	..	0·0094	0·0053	..	..	..	..	..	0·0023	0·0088	0·050
						10. *Mianwali*									
0—1	0·0122	..	0·0143	..	..	0·0033	..	..	0·0029	0·0093	0·0006	..	..	0·0244	0·090
1—2	0·0053	..	0·0251	..	..	0·0060	0·0004	..	..	0·0036	..	..	0·0026	0·0146	0·050
2—3	0·0058	..	0·0206	..	..	0·0032	..	..	0·0021	..	..	0·0062	0·0061	0·0102	0·043
3—4	0·0007	..	0·0235	..	..	0·0033	..	..	0·0010	..	..	0·0039	0·0046	0·0088	0·035
4—5	..	..	0·0182	..	..	0·0033	..	..	0·0021	..	..	0·0026	0·0030	0·0117	0·033
						51. *Taliparamba*									
0—1	..	..	0·0116	0·0029	0·0008	..	..	0·0064	..	..	0·0046	..	..	0·0140	0·070
1—2	..	..	0·0162	..	..	0·0011	..	0·0100	..	..	0·0046	..	..	0·0134	0·060
2—3	..	..	0·0142	..	..	0·0003	..	0·0105	..	..	0·0046	..	..	0·0113	0·050
3—4	..	..	0·0101	..	..	0·0065	..	0·0022	..	..	0·0031	..	..	0·0169	0·045
4—5	..	..	0·0081	..	..	0·0031	0·0013	0·0033	..	..	0·0031	..	..	0·0154	0·033
						7 *Gurdaspur* $Mg(NO_3)_2$									
0—1	0·0005	..	0·0290	0·0036	..	..	0·0022	0·0130	..	..	0·0061	..	..	0·0136	0·084
1—2	0·0181	..	0·0145	..	..	0·0069	0·0051	0·0043	..	..	0·0006	..	..	0·0293	0·084
2—3	..	..	0·0145	0·0072	0·0035	..	..	0·0115	..	..	0·0030	..	..	0·0039	0·060
3—4	0·0041	..	0·0145	0·0035	0·0003	..	..	0·0090	..	..	0·0024	..	..	0·0153	0·061
4—5	0·0151	..	0·0116	0·0005	..	..	0·0054	0·0046	..	..	0·0041	..	..	0·0228	0·076
						35. *Jorhat* $Mg(HCO_3)_2$									
0—1	..	..	0·0087	0·0017	0·0023	..	..	0·0226	..	..	0·0006	..	..	..	0·071
1—2	..	..	0·0029	..	0·0050	..	..	0·0087	..	..	0·0029	..	..	0·0110	0·050
2—3	..	..	0·0058	..	0·0030	..	..	0·0052	..	..	0·0012	..	..	0·0173	0·052
3—4	..	..	0·0058	..	0·0002	..	..	0·0080	..	..	0·0015	..	..	0·0107	0·037
4—5	..	..	0·0041	..	..	0·0016	..	0·0046	..	..	0·0031	..	..	0·0138	0·040
						39. *Rangpur*									
0—1	..	..	0·0081	..	..	0·0035	..	0·0055	..	..	0·0076	..	..	0·0070	0·046
1—2	..	..	0·0093	..	0·0019	..	..	0·0039	..	..	0·0038	..	..	0·0100	0·037
2—3	..	..	0·0053	..	0·0019	..	..	0·0039	..	..	0·0095	..	..	0·0006	0·028
3—4	..	..	0·0040	..	..	0·0011	..	0·0032	..	..	0·0019	..	..	0·0062	0·017
4—5	..	..	0·0053	..	0·0019	..	..	0·0078	..	..	0·0020	..	..	..	0·023
						22. *Ranchi*									
0—1	..	..	0·0087	..	0·0079	..	..	0·0053	..	..	0·0033	..	..	0·0523	0·093
1—2	..	..	0·0101	..	..	0·0013	..	0·0016	..	..	0·0033	..	..	..	0·016
2—3	..	..	0·0116	0·0021	..	..	0·0032	0·0072	..	..	0·0049	..	..	0·0283	0·068
3—4	..	..	0·0174	..	0·0033	..	..	0·0090	..	..	0·0074	..	..	0·0140	0·064
4—5	..	..	0·0116	0·0029	0·0130	..	..	0·0061	..	..	0·0044	..	..	0·0255	0·087

12. *Karachi*															
0—1	0·0158	..	0·0203	0·0204	0·0460	..	..	0·0278	..	..	0·0484	..	..	0·0872	0·320
1—2	0·0043	..	0·0260	0·0051	..	..	0·0108	..	..	0·0282	0·0036	..	..	0·1143	0·190
2—3	0·0016	..	0·0231	0·0658	..	..	0·0243	..	..	0·0251	..	..	0·0312	0·0995	0·270
3—4	0·0009	..	0·0231	0·0919	..	..	0·0297	..	..	0·0251	..	..	0·0053	0·1097	0·305
4—5	0·0017	..	0·0231	0·0437	..	..	0·0108	..	..	0·0106	0·0071	..	..	0·1144	0·235
24. *Nagpur*															
0—1	..	..	0·0425	..	..	..	..	..	0·0010	..	..	0·0121	0·0015	0·0146	0·070
1—2	..	..	0·0303	..	..	0·0092	0·0006	..	..	0·0009	..	..	0·0017	0·0088	0·050
2—3	..	..	0·0243	..	..	0·0131	..	..	0·0010	..	..	0·0039	0·0015	0·0117	0·048
3—4	..	..	0·0182	..	..	0·0131	..	..	..	..	..	0·0170	0·0015	0·0088	0·048
4—5	..	..	0·0243	..	..	0·0099	..	..	0·0031	..	..	0·0179	0·0015	0·0102	0·055
3. *Lahore*															
0—1	..	..	0·0243	..	..	0·0066	..	..	..	0·0027	..	0·0153	0·0024	0·0073	0·058
1—2	0·0087	..	0·0258	..	..	0·0066	..	..	..	..	..	0·0107	0·0305	0·0351	0·115
2—3	0·0224	..	0·0405	0·0153	..	..	0·0135	..	..	0·0009	..	..	0·0586	0·0761	0·283
3—4	0·0112	..	0·0434	0·0069	..	..	0·0135	..	..	..	..	..	0·0803	0·0673	0·230
4—5	0·0006	..	0·0405	0·0198	..	..	0·0135	..	..	..	..	..	0·1416	0·0219	0·245
9. *Lyallpur*															
0—1	..	..	0·0318	0·0021	..	..	0·0020	0·0049	..	..	0·0146	..	..	0·0060	0·060
1—2	0·0033	..	0·0318	0·0317	..	..	0·0081	0·0064	..	..	0·0077	..	..	0·0036	0·105
2—3	0·0342	..	0·0231	0·0467	0·0033	..	..	0·0171	..	..	0·0061	..	..	..	0·183
3—4	0·0658	..	0·0202	0·0131	0·0015	..	..	0·0107	..	..	0·0031	..	..	..	0·165
4—5	0·0421	..	0·0202	0·0102	0·0089	..	..	0·0107	..	..	0·0046	..	..	..	0·150
8. *Kangra*															
0—1	0·0005	..	0·0203	0·0043	0·0070	..	..	0·0082	..	..	0·0041	..	..	0·0015	0·072
1—2	0·0110	..	0·0174	0·0092	..	..	0·0007	0·0071	..	..	0·0046	..	..	0·0148	0·106
2—3	..	..	0·0174	0·0061	0·0104	..	..	0·0102	..	..	0·0059	..	..	..	0·105
3—4	..	..	0·0174	0·0075	0·0059	..	..	..	..	..	0·0046	..	..	0·0158	0·077
4—5	0·0192	..	0·0174	0·0030	..	..	0·0043	..	..	0·0053	..	..	0·0004	0·0261	0·097
19. *Padrauna*															
0—1	..	..	0·0492	0·0044	..	..	0·0012	0·0050	..	..	0·0099	..	..	0·0270	0·091
1—2	..	..	0·0280	..	..	..	0·0056	..	..	..	0·0015	..	..	0·0049	0·030
2—3	..	..	0·0290	0·0054	0·0032	..	..	0·0086	..	..	0·0109	..	..	0·0545	0·103
3—4	..	..	0·0231	0·0010	..	..	0·0009	0·0014	..	..	0·0073	..	..	0·0159	0·040
4—5	0·0009	..	0·0214	..	..	0·0083	..	..	0·0013	0·0074	..	..	..	0·0158	0·051
33. *Makrera*															
0—1	0·0053	..	0·0190	..	..	0·0120	..	..	0·0208	0·0020	..	..	0·0058	0·0198	0·080
1—2	0·0013	..	0·0319	0·0129	..	..	0·0037	0·0127	..	..	0·0114	..	..	0·0347	0·119
2—3	..	..	0·0319	..	0·0321	..	..	0·0235	..	..	0·0076	..	..	0·0947	0·243
3—4	..	..	0·0319	0·0439	..	..	..	0·0235	..	..	0·0019	..	..	0·1974	0·321
4—5	..	..	0·0319	0·0106	..	..	0·0396	..	..	0·0089	..	..	..	0·1733	0·262
40. *Chinsura*															
0—1	..	..	0·0162	..	..	0·0010	..	0·0072	..	..	..	..	..	0·0077	0·051
1—2	..	..	0·0320	..	..	..	0·0025	0·0058	..	..	..	..	..	0·0126	0·060
2—3	..	..	0·0372	0·0028	0·0027	..	..	0·0117	..	..	0·0019	..	..	0·0159	0·094
3—4	..	..	0·0372	0·0014	0·0066	..	..	0·0117	..	..	0·0057	..	..	0·0072	0·080
4—5	..	..	0·0194	0·0014	0·0101	..	..	0·0078	..	..	0·0038	..	..	0·0097	0·078
37. *Sylhet*															
0—1	..	..	0·0058	..	0·0002	..	..	0·0074	..	..	0·0010	..	..	0·0058	0·039
1—2	..	..	0·0027	..	0·0010	..	..	0·0039	..	..	..	..	..	0·0125	0·036
2—3	..	..	0·0027	..	0·0037	..	..	0·0039	..	..	0·0057	..	..	0·0215	0·050
4—4	..	..	0·0027	..	0·0037	..	..	0·0039	..	..	0·0076	..	..	0·0365	0·074
3—5	..	..	0·0040	..	..	0·0011	..	0·0031	..	..	0·0038	..	..	0·0119	0·030

APPENDIX—*contd.*

The water-soluble salt contents of soil profiles

Depth in ft.	Ca $(NO_3)_2$	$CaCO_3$	Ca $(HCO_3)_2$	$CaSO_4$	$CaCl_2$	Mg- $(HCO_3)_2$	$MgSO_4$	$MgCl_2$	$KHCO_3$	K_2SO_4	KCl	Na HCO_3	Na_2SO_4	NaCl	Total solids
						2. Haripur Hazara									
0—1	..	..	0·0376	0·0029	0·0092	..	..	0·0128	..	..	0·0023	..	..	0·0063	0·088
1—2	..	..	0·0318	0·0044	0·0079	..	..	0·0128	..	..	..	..	..	0·0111	0·078
2—3	..	..	0·0347	0·0044	0·0059	..	..	0·0107	..	..	0·0008	..	..	0·0108	0·085
3—4	..	..	0·0405	0·0058	0·0007	..	..	0·0128	..	..	..	..	..	0·0230	0·105
4—5	..	..	0·0405	..	..	..	0·0039	0·0034	..	..	0·0008	..	..	0·0172	0·075
						34. Tabiji									
0—1	..	..	0·0289	0·0058	0·0017	..	..	0·0086	..	..	0·0031	..	..	0·0160	0·068
1—2	..	..	0·0231	0·0160	0·0126	..	..	0·0150	..	..	0·0031	..	..	0·0464	0·128
2—3	..	..	0·0162	..	..	0·0099	..	..	0·0010	..	..	0·0040	0·0198	0·0658	0·105
3—4	..	..	0·0040	..	..	0·0066	..	..	0·0010	..	..	0·0414	0·0198	0·0600	0·113
4—5	..	..	0·0061	..	..	0·0066	..	..	0·0010	..	..	0·0213	0·0076	0·0249	0·050
						52. Koilpatti									
0—1	..	..	0·0101	..	..	0·0066	..	..	..	..	..	0·0660	0·0091	0·0234	0·093
1—2	..	..	0·0121	..	..	0·0066	..	..	0·0031	..	..	0·0733	0·0244	0·0716	0·165
2—3	..	..	0·0608	0·3055	..	..	0·1758	..	..	0·0036	..	..	0·3857	0·2516	1·280
3—4	..	..	0·0434	0·6963	..	..	0·3110	..	..	0·0054	..	..	0·5235	0·3452	2·190
4—5	..	..	0·0372	0·6139	..	..	0·3191	..	..	0·0063	..	..	0·4601	0·3335	1·903
						36. Karimganj									
0—1	..	..	0·0116	0·0029	0·0035	..	..	0·0086	..	..	0·0015	..	..	0·0153	0·065
1—2	..	..	0·0087	0·0015	0·0039	..	..	0·0128	..	..	0·0023	..	..	0·0178	0·070
2—3	..	..	0·0087	0·0073	0·0033	..	..	0·0150	..	..	0·0023	..	..	0·0333	0·095
3—4	..	..	0·0087	0·0015	0·0067	..	..	0·0128	..	..	..	..	..	0·0269	0·075
4—5	..	..	0·0087	0·0015	0·0067	..	..	0·0128	..	..	0·0015	..	..	0·0257	0·075
						54. Hagari									
					$MgCO_3$						Na_2CO_3				
0—1	..	0·0025	..	..	0·0019	..	..	..	..	..	0·0025	0·1020	0·0137	0·0380	0·135
1—2	0·0008	0·0020	..	..	..	..	..	..	..	..	0·0054	0·0840	0·0974	0·1551	0·335
2—3	0·0010	0·0036	0·0463	0·0064	..	..	0·0189	..	..	0·0018	..	..	0·5313	0·2312	0·845
3—4	..	..	0·0579	0·0125	..	..	0·0216	..	..	..	..	..	0·5399	0·2136	0·855
4—5	..	..	0·0121	..	..	0·0082	..	..	..	..	..	0·0677	0·2223	0·2077	0·505
						56. Samalkot									
											K_2CO_3				
0—1	..	0·0025	..	..	..	..	..	..	0·0092	..	0·0015	0·0463	0·0137	0·0293	0·110
1—2	..	0·0036	0·0023	..	..	0·0033	..	..	0·0144	..	..	0·0417	0·0091	0·0497	0·175
2—3	..	0·0025	..	..	0·0019	..	..	..	0·0138	..	0·0035	0·0245	0·0091	0·0439	0·155
						13. Mirpurkhas									
0—1	0·0026	..	0·0292	0·0085	0·0073	..	..	0·0117	..	..	0·0267	..	..	..	0·095
1—2	0·0013	..	0·0319	0·0014	0·0038	..	..	0·0117	..	..	0·0133	..	..	0·0041	0·070
2—3	..	..	0·0121	..	..	0·0240	..	..	0·0130	0·0036	0·0309	..	..	0·0203	0·080
3—4	..	..	0·0324	..	..	0·0128	0·0093	..	..	0·0011	0·0391	..	..	0·0222	0·098
4—5	..	..	0·0202	..	..	0·0120	..	..	0·0045	0·0651	..	..	0·0076	0·0413	0·075

25. *Akola*															
0—1	..	..	..	..	..	0·0066	..	..	0·0010	..	..	0·0234	0·0030	0·0059	0·053
1—2	..	..	0·0243	..	..	0·0033	..	..	0·0010	..	..	0·0644	0·0015	0·0059	0·058
2—3	..	..	..	..	..	0·0033	..	..	0·0021	..	..	0·0845	0·0030	0·0088	0·070
3—4	..	..	..	..	..	0·0067	..	..	0·0041	..	..	0·0940	0·0030	0·0059	0·083
4—5	..	..	..	..	..	0·0033	..	..	..	..	..	0·1192	0·0046	0·0117	0·098
27. *Labhandi*															
0—1	..	..	0·0142	..	..	0·0055	..	..	..	..	..	..	..	0·0039	0·036
1—2	..	..	0·0101	..	..	0·0060	..	..	..	..	..	0·0034	..	0·0044	0·035
2—3	..	..	0·0061	..	..	0·0053	..	..	..	..	..	0·0115	..	0·0029	0·032
3—4	..	..	0·0122	..	..	0·0083	..	..	0·0016	..	..	0·0303	..	0·0073	0·054
4—5	..	..	0·0134	..	..	0·0130	..	..	0·0057	..	..	0·0260	..	0·0044	0·060
26. *Warasoeni*															
0—1	..	..	0·0324	..	..	0·0033	..	..	0·0020	..	0·0085	..	..	0·0124	0·068
1—2	..	..	0·0681	..	..	..	..	..	0·0010	..	..	0·0058	0·0030	0·0073	0·023
2—3	..	..	0·0162	..	..	..	..	..	0·0082	..	..	0·0003	0·0046	0·0102	0·033
3—4	..	..	0·0121	..	..	..	..	..	0·0031	..	..	0·0058	0·0061	0·0102	0·025
4—5	..	..	0·0364	..	..	..	..	..	0·0015	0·0032	..	..	0·0050	0·0102	0·073
50. *Coimbatore*															
0—1	..	..	0·0142	..	..	0·0003	0·0039	0·0010	..	..	0·0015	..	..	0·0034	0·035
1—2	..	..	0·0142	..	..	0·0055	0·0009	..	..	0·0006	0·0010	..	..	0·0050	0·033
2—3½	..	..	0·0445	..	..	0·0016	0·0039	0·0044	..	..	0·0008	..	..	0·0086	0·055
3½—4½	..	..	0·0404	..	..	0·0027	0·0039	0·0016	..	..	0·0008	..	..	0·0106	0·050
55. *Nandyal*				$MgCO_3$				K_2CO_3			Na_2CO_3				
0—1	0·0024	..	..	..	..	..	..	..	..	..	0·0076	0·1110	0·0152	0·0088	0·155
1—2	0·0008	0·0008	..	0·0019	..	..	..	..	..	..	0·0006	0·1140	0·0168	0·0117	0·144
2—3	..	0·0013	..	0·0619	..	..	..	0·0007	..	..	0·0033	0·1200	0·0244	0·0629	0·203
3—4	..	0·0036	0·0023	..	..	0·0033	..	..	0·2021	..	..	0·1091	0·0533	0·0585	0·225
4—5	..	0·0025	..	0·0019	..	..	..	..	..	..	0·0101	0·1200	0·1188	0·0585	0·290
57. *Anakapalle*				$CaSO_4$			$MgCl_2$			KCl					
0—1	..	..	0·0116	0·0005	..	..	0·0047	0·0025	..	..	0·0008	..	..	0·0139	0·040
1—2	..	..	0·0145	0·0014	..	..	0·0026	0·0044	..	..	0·0015	..	..	0·0110	0·040
2—3	..	..	0·0116	0·0005	..	..	0·0035	0·0037	..	..	..	..	..	0·0101	0·040
3—4	..	..	0·0116	0·0005	..	..	0·0022	0·0026	..	..	0·0008	..	..	0·0123	0·040
4—5	..	..	0·0116	0·0058	0·0039	..	..	0·0021	..	..	..	..	..	0·0210	0·073
58. *Berhampur*															
0—1	..	..	0·0101	..	..	0·0039	0·0022	..	..	0·0025	0·0040	..	..	0·0100	0·035
1—2	..	..	0·0040	..	..	..	..	..	0·0129	0·0022	..	..	0·0027	0·0146	0·035
2—3	..	..	0·0061	..	..	..	..	..	0·0165	..	..	0·0009	0·0061	0·0132	0·043
3—4	..	..	0·0040	..	..	0·0033	..	..	0·0084	0·0053	..	..	0·0003	0·0132	0·045
4—5	..	..	0·0020	..	..	..	..	..	0·0190	0·0015	..	..	0·0064	0·0161	0·048
11. *Sakrand*															
0—1	..	..	0·0376	0·0073	..	..	0·0151	..	..	0·0118	..	..	0·0114	0·0154	0·129
1—2	0·0024	..	0·0376	0·0024	..	..	0·0178	..	..	0·0161	0·0064	..	..	0·0070	0·084
2—3	0·0251	..	0·0319	0·0817	..	..	0·0232	0·0021	..	..	0·0289	..	..	0·0240	0·189
3—4	0·0527	..	0·0261	0·0115	..	..	0·0918	..	..	0·1116	0·0354	..	..	0·2092	0·826
4—5	0·0210	..	0·0319	0·2733	..	..	0·1577	..	..	0·1814	..	..	..	0·1182	1·050
48. *Padegaon*															
0—1	0·0009	..	0·0052	..	..	0·0033	..	..	..	..	..	0·0508	0·0289	0·0117	0·097
1—2	..	..	0·0040	..	..	0·0033	..	..	0·0021	..	..	0·0743	0·0152	0·0205	0·095
2—3	..	..	0·0061	..	..	0·0033	..	..	0·0052	..	..	0·0756	0·0152	0·0293	0·115
3—4	..	..	0·0463	0·0155	..	..	0·0243	..	..	0·0072	..	..	0·2416	0·0454	0·333
4—5	..	..	0·0318	0·6642	..	..	0·1783	..	..	0·0162	..	..	0·4227	0·0585	1·508

APPENDIX—*contd.*

The water-soluble salt contents of soil profiles

Depth in ft.	$Ca(NO_3)_2$	$CaCO_3$	$Ca(HCO_3)_2$	$CaSO_4$	$CaCl_2$	$Mg(HCO_3)_2$	$MgSO_4$	$MgCl_2$	$KHCO_3$	K_2SO_4	KCl	$NaHCO_3$	Na_2SO_4	NaCl	Totals solid
18. *Shahjahanpur*															
0—1	..	..	0·0203	..	..	0·0026	0·0018	0·0012	..	..	0·0018	..	..	0·0021	0·025
1—2	..	..	0·0142	..	..	0·0045	..	..	0·0012	..	0·0014	..	..	..	0·020
2—3	..	..	0·0116	0·0070	..	..	..	0·0057	..	..	..	..	..	..	0·029
3—4	..	..	0·0081	..	..	0·0031	0·0054	..	..	..	..	..	..	0·0042	0·033
4—5	..	..	0·0081	..	..	0·0005	0·0036	0·0012	..	..	..	..	..	0·0044	0·015
30. *Powerkhera*															
0—1	..	..	0·0324	..	..	0·0047	..	0·0017	..	..	0·0023	..	..	0·0034	0·044
1—2	..	..	0·0324	..	..	0·0047	..	0·0022	..	..	0·0029	..	..	0·0009	0·039
2—3	..	..	0·0243	..	..	0·0068	..	0·0004	..	..	0·0031	..	..	0·0030	0·040
3—4	..	..	0·0263	..	..	0·0090	..	..	0·0013	..	0·0013	..	..	0·0033	0·043
4—5	..	..	0·0385	..	..	0·0018	0·0020	0·0024	..	..	0·0028	..	..	0·0021	0·043
31. *Indore*															
0—1	..	..	0·0303	..	..	0·0099	..	..	0·0010	..	..	0·0044	0·0061	0·0088	0·055
1—2	..	..	0·0303	..	..	0·0040	0·0026	0·0018	..	..	0·0008	..	..	0·0038	0·040
2—3	..	..	0·0376	0·0041	..	..	0·0041	0·0031	..	..	0·0015	..	..	0·0066	0·050
3—4	..	..	0·0324	..	..	0·0074	0·0064	0·0008	..	..	..	..	..	0·0122	0·055
4—5	..	..	0·0202	..	..	0·0099	..	..	..	..	..	0·0067	0·0046	0·0073	0·043
43. *Sirsi*															
0—1	..	..	..	..	..	0·0060	..	..	0·0033	..	0·0014	..	..	0·0039	0·028
1—2	..	..	..	..	..	0·0060	..	..	0·0033	..	0·0014	..	..	0·0055	0·020
2—3	..	..	0·0040	..	..	0·0047	..	0·0008	..	..	0·0019	..	..	0·0041	0·023
3—4	0·0013	..	0·0027	..	..	0·0060	..	..	..	..	0·0019	..	..	0·0051	0·027
4—5	0·0013	..	..	..	..	0·0048	..	0·0008	..	..	0·0019	..	..	0·0041	0·023
49. *Surat*															
0—1	..	..	0·0202	..	..	0·0081	..	0·0025	..	..	0·0024	..	..	..	0·043
1—2	..	..	0·0202	..	..	0·0129	..	..	..	..	..	..	..	0·0066	0·042
2—3	..	..	0·0243	..	..	0·0069	..	0·0033	..	..	0·0019	..	..	0·0010	0·044
3—4	..	..	0·0243	..	..	0·0093	..	0·0018	..	..	0·0019	..	..	0·0062	0·045
4—5	..	..	0·0243	..	..	0·0093	..	0·0018	..	..	0·0019	..	..	0·0095	0·045
28. *Chandkhuri*															
0—5 in.	..	..	0·0081	..	..	0·0066	..	..	0·0031	..	..	0·0085	0·0015	0·0073	0·020
5—16 in.	..	..	0·0142	..	..	0·0033	..	..	0·0021	..	..	0·0098	0·0015	0·0073	0·025
16—28 in.	..	..	0·0182	..	..	0·0066	..	..	0·0031	..	..	0·0010	0·0015	0·0102	0·025
28—40 in.	..	..	0·0081	..	..	0·0033	..	..	..	..	..	0·0058	0·0030	0·0073	0·028
40—52 in.	..	..	0·0081	..	..	0·0031	0·0026	0·0002	..	..	..	..	..	0·0071	0·025
52—60 in.	..	..	0·0081	..	..	0·0031	0·0001	..	..	..	..	..	0·0014	0·0073	0·028
29. *Kheri Adhartal*															
0—1	..	..	0·0405	0·0044	0·0049	..	..	0·0107	..	..	..	..	..	..	0·043
1—2	..	..	0·0404	..	..	0·0053	0·0039	0·0042	..	..	0·0015	..	..	0·0053	0·040
2—3	..	..	0·0405	0·0016	..	..	0·0011	0·0077	..	..	..	..	..	..	0·038
3—4	..	..	0·0384	..	..	0·0045	0·0026	0·0036	..	..	..	..	..	..	0·043
4—5	..	..	0·0344	..	..	0·0029	0·0039	0·0057	..	..	0·0008	..	..	..	0·040

32. *Kharua*															
0—1	..	..	0·0546	..	..	0·0030	0·0064	0·0037	..	..	..	..	..	0·0218	0·063
1—2	..	..	0·0434	0·0009	..	..	0·0031	0·0040	..	..	..	..	..	0·0126	0·048
2—3	..	..	0·0364	..	..	0·0063	0·0039	0·0014	..	..	..	..	..	0·0203	0·043
3—4	..	..	0·0384	..	..	0·0011	0·0052	0·0011	..	..	..	..	..	0·0103	0·045
4—5	..	..	0·0283	..	..	0·0066	..	..	..	..	..	0·0021	0·0046	0·0012	0·045
38. *Dacca*															
0—1	..	..	0·0101	..	..	0·0013	0·0026	0·0014	..	..	..	..	..	0·0036	0·035
1—2	..	..	0·0040	..	..	0·0033	..	..	..	..	..	0·0100	0·0015	0·0073	0·028
2—3	..	..	0·0040	..	..	0·0033	..	..	..	..	..	0·0100	0·0015	0·0073	0·018
3—4	..	..	0·0040	..	..	0·0066	..	..	..	..	..	0·0033	0·0015	0·0073	0·020
4—5	..	..	0·0040	..	..	0·0033	..	..	0·0012	0·0007	..	..	0·0025	0·0044	0·018
59. *Pusa*															
0—8 in.	0·0020	..	0·0404	..	..	0·0018	0·0066	..	..	..	..	..	0·0059	0·0039	0·048
1—2	0·0012	..	0·0311	..	..	0·0033	0·0039	0·0012	..	..	0·0015	..	..	0·0046	0·055
2—3	0·0079	..	0·0318	0·0044	0·0025	..	..	0·0064	..	..	..	..	..	0·0041	0·068
3—4	0·0063	..	0·0289	0·0044	0·0042	..	..	0·0107	..	..	..	..	..	..	0·070
4—5	0·0045	..	0·0260	0·0033	..	..	0·0023	0·0068	..	..	..	..	..	0·0048	0·055
60. *Delhi*															
0—1	..	..	0·0324	..	..	0·0066	..	..	0·0010	..	..	..	0·0061	0·0088	0·043
1—2	..	..	0·0283	..	..	0·0006	0·0022	..	..	..	..	..	0·0004	0·0073	0·040
2—3	..	..	0,0269	..	..	0·0018	0·0015	..	..	..	..	..	0·0012	0·0073	0·038
3—4	..	..	0·0283	..	..	0·0033	..	..	..	..	..	0·0029	0·0030	0·0073	0·043
4—4ft. 10 in.	..	..	0·0222	..	..	0·0099	..	..	..	..	..	0·0016	0·0030	0·0044	0·040

COMPARATIVE STUDIES ON INDIAN SOILS.

VII. CARBON AND NITROGEN STATUS OF INDIAN SOILS AND THEIR PROFILES

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(With one text-figure)

In Part I of this series, Viswanath and Ukil [1944] dealt with the regional and environmental factors associated with Indian soils. The carbon and nitrogen status of a soil and the ratio of carbon by nitrogen are important considerations both from the points of view of the developmental process in the soil and its agricultural value. A great deal of information on the carbon and nitrogen ratio of cold and temperate regions of the world is available but very little information is available on Indian soils. It is well known that cultivation brings about changes in the carbon and nitrogen levels of a soil. To obtain a precise information on the carbon and nitrogen contents of uncultivated and undisturbed soils, 43 profiles samples collected from all over India in the months of February and March, 1937, have been examined. The data for the carbon and nitrogen contents of the profiles have been obtained and these and the calculated carbon-nitrogen ratios are given in the appendix.

Experimental

Total nitrogen was estimated by the wet digestion method of Bal [1925] and by the dry digestion method described in *A. O. A. C.* [1935]. Organic carbon was estimated by the dry combustion method of *A. O. A. C.* [1935]. The organic carbon content has been obtained after making allowance for carbon-dioxide of carbonates estimated in the original sample and in the residual soil after dry combusion. Precaution was taken to ascertain that the soil samples taken for carbon estimation did not contain pieces of wood, charcoal bits, etc.

Results

For purposes of determining the carbon and nitrogen status of the soils in relation to climate and colour classification, it will facilitate discussion if the soils are listed as shown in Table I.

TABLE I

Grouping of the soils on climatic and colour basis

(The numbers correspond to those given in the appendix)

Climatic division / Colour division	Arid	Semi-arid	Humid	Per-humid
Black . . .	—	45. Akola 31. Indore 32. Kharua 48. Padegaon 92. Surat 52. Koilpatti 54. Hagari 55. Nandyal	24. Nagpur 27. Labhandi 29. Kheri-Adhartal 30. Powerkhera 26. Samalkot	—
Brown . . .	2. Haripur Hazara 9. Lyallpur	34. Tabiji 50. Coimbatore 57. Anakapalle 60. Delhi	40. Chinsura 18. Shahjahanpur	8. Kangra 35. Jorhat 36. Karimganj
Red . . .	—	—	26. Waraseoni 22. Ranchi 28. Chandkhuri	73. Sylhet 38. Dacca 35. Sirsi 51. Taliparamb
Grey and pink . .	10. Mianwali	3. Lahore 7. Gurdaspur 33. Makrera	58. Berhampur	39. Rangpur
Calcareous . .	1. Peshawar 11. Sakrand 12. Karachi	—	19. Padrauna 59. Pusa	

In the brown soils of the arid region the carbon content decreases more rapidly with depth than the nitrogen content and the C/N ratio narrows down with depth. The nitrogen content of the brown soils from Tabiji, Coimbatore and Anakapalle of the semi-arid zone does not differ much with depth and so is the case with carbon. The carbon-nitrogen ratio on the average is above 11 with slight variations in the profile.

In Chinsura and Shahjahanpur soils of the humid region the carbon content is either steady or increases slightly within the first three feet and then decreases in the fourth and fifth foot. The carbon contents in the first foot of Chinsura and Shahjahanpur are 0·69 and 0·22 per cent respectively. The nitrogen content of Chinsura soil varies from 0·086 per cent in the first foot depth to 0·051 at the fifth foot. At Shahjahanpur the soil nitrogen is practically the same 0·032 at the first and fifth foot. The C/N ratio of the brown soils in the humid zone increases in the second and third foot and narrows down later. Four profiles of brown soil from Kangra, Jorhat, Karimganj and Sylhet of the per-humid region show a gradual decrease of carbon and nitrogen with depth. The surface soils contain high amounts of carbon and nitrogen with an average C/N ratio of 12·2, narrowing with depth. There are definite signs of leaching and accumlation of carbon in the second foot depth of Sylhet soil.

In grey and pink soils of the arid zone the carbon and nitrogen contents decrease with depth and C/N ratio on an average is high with values in the first foot of 11·4 in Mianwali and 16·7 in Mirpurkhas. The average C/N ratio for the profile is above 10. The grey and pink soils of Lahore, Gurdaspur and Makrera in the semi-arid region contain a fairly high proportion of nitrogen and the level is almost maintained in all depths. The carbon content is low and the C/N ratio is very narrow (5·0) with slight decrease in the profile. Makrera soils contain over 15 per cent lime as calcium carbonate and the average C/N ratio in the first three feet is 12·9 and 7·6 in the 3-5 ft. depth. In Berhampur soil of the humid region the nitrogen content remained steady in the profile but the carbon content decreases with depth and the C/N ratio narrows from 11·21 at the surface to 6·0 at the last depth. In Rangpur profile of per-humid zone both carbon and nitrogen decrease with depth and the C/N ratio narrows down from 13·8 at the surface to 1·9 at the last depth.

The black soils examined are located in the semi-arid and humid regions. The nitrogen content of the surface soils in the semi-arid region varies from 0·022 per cent in Koilpatti to 0·076 in the black soil of Surat. The nitrogen content at the lower depths, though lower than in the surface soils, remains fairly uniform. Similarly the carbon content of surface soil varies from 0·50 per cent at Hagari to 1·26 per cent at Kharua. The C/N ratio in all the profiles does not vary much with depth and the ratios are generally wide. The average C/N ratios of the profiles from Kharua, Padegaon, Koilpatti, Hagari and Nandyal are 20·7, 19·5, 21·8, 15·3 and 20·8 respectively. The black soils of the humid region are from Nagpur, Labhandi, Kheri, Powerkhera and Samalkot, the last mentioned being an alluvial black soil. The carbon and nitrogen contents in the surface soils are similar to those in the semi-arid region, and decrease slightly with depth. The C/N ratios of the surface soils vary between 10·7 and 14·0. Considering the averages for the profile, only Nagpur and Kheri soils show the wide ratios of 16·3 and 17·1 respectively. There is a clear indication that as the amount of rainfall increases the C/N ratio narrows down in the black soils. This is borne out when the average C/N ratio of the black soils of the semi-arid and humid region are compared, the ratio decreasing from 14·6 in the semi-arid to 12·9 in the humid zone.

The red soil profiles are from the humid and per-humid regions. In the profiles from Ranchi and Chandkhuri of the humid region there are indications of leaching down of organic matter and accumulation in the lower horizons. The surface soil and the layers below contain 0·036 per cent nitrogen at Ranchi, while it is 0·062 in the surface soil and 0·08 in the second layer decreasing later with depth in the Chandkhuri profile. The C/N ratio of the surface soils is near about 14·0 but the ratio decreases with depth. The average C/N ratio for the profiles of Ranchi and Chandkhuri is 10 and 12·7 respectively. The profiles of Sirsi and Taliparamba are from the per-humid zone. The surface soils in both the places contain high amounts of carbon and nitrogen, which decrease with the depth of the profile. The C/N ratio of Sirsi profile narrows down from 10·4 at the surface to 5·0 in the fifth foot. In the case of Taliparamba soil the C/N ratio does not show such wide difference with depth, C/N ratio in the first foot being 11·8 and 9·8 in the fifth foot

The calcareous soils from Peshawar, Sakrand and Karachi in the arid region and two soils from Padrauna and Pusa have also been examined. In Peshawar soil the surface soil has a nitrogen value of 0·077 per cent and from the second foot downwards remains constant with 0·03 per cent. The carbon content also decreases proportionately and the C/N ratio is fairly uniform with an average value of 11·8. In Sakrand soil also the surface value for nitrogen is 0·052 and remains steady at 0·03 in the second foot and downwards. Carbon decreases with depth with an accumulation in the third and fourth foot. The C/N ratio in the surface soil is narrow but widens in the lower depths. The Karachi soil is very poor in nitrogen, 0·018 per cent, which remains constant in the profile. The C/N ratio decreases from 17·9 in the surface to 8·8 in the last depth. In Padrauna sample the carbon content is 1·1 per cent, nitrogen 0·099 in the surface sample but both carbon and nitrogen decrease rapidly with depth and the average C/N ratio for the profile is 10·7. In Pusa soil the nitrogen content is low, 0·03 per cent, and the C/N ratio is wide with a value of 14·06 in the surface sample and an average value of 16·8 for the profile.

Confining the attention to the surface soils, the average carbon and nitrogen content and the C/N ratios in the different climatic zones and colour groups of soils are as shown in Table II. The calcareous soils are included in Table II as a distinct group.

TABLE II

The average carbon and nitrogen content and C/N ratios in different climatic zones and colour groups

(The blanks in the table denote that there are no soils of that colour in the paticular climatic zone)

Climatic division / Colour division	Arid	Semi-arid	Humid	Per-humid
Black—				
Organic (C) carbon mg. per cent	..	717	709	..
Nitrogen (N) mg. per cent	..	49	55	..
C/N	..	14·6	12·9	..
Brown—				
C	645	362	..	1,096
N	68	33	..	90
C/N	9·5	11·0	..	12·2
Red—				
C	..	..	680	1,539
N	..	..	49	137
C/N	..	..	13·9	11·2
Grey and pink—				
C	513	486	247	1,430
N	38	65	22	105
C/N	13·5	7·5	11·2	13·6
Calcareous—				
C	495	..	1,100	..
N	49	..	99	..
C/N	10·1	..	11·1	..
Average—				
C	543	592	639	1,234
N	51	49	54·6	102
C/N	10·6	12·2	11·7	12·1

DISCUSSION

The influence of climate on humus in the soil has been discussed by Lang [1920]. Smolik [1926] has shown that total organic matter shows no variation with the rain factor, but that the chemical composition of humus appeared to be related to climate. Russel and McRuer [1927] in their investigation of organic matter and nitrogen content of virgin Nebraska soils found a linear relation-

ship between nitrogen and annual rainfall after reducing the soils to a common hygroscopic coefficient to eliminate variation due to texture.

Hans Jenny [1929, 1932] has shown a relationship between mean annual temperature and total nitrogen content. According to him climate is the outstanding factor which controls the nitrogen level of the loamy soils of the United States examined by him. Vegetation is the next important factor, while topography and parent material probably rank third and fourth. The nitrogen values for soils of Russia, Norway, Denmark, Switzerland and Italy do not seem to contradict Jenny's view. But the soils of Palestine do not come under this category.

The Indian soils which have been grouped into arid, semi-arid, humid and per-humid zones on the basis of N.S.Q., on lines similar to those of Jenny, give a picture different from the soils of the United States or Europe. In India the mean annual temperatures for a majority of places from where the soils have been studied are between 75°. to 80°F. The total carbon and nitrogen contents of the American and European soils are in many cases four times the values and even more as compared to those of India. Considering the values for the nitrogen contents of soils in the several zones, it is seen that if the data are plotted against temperature the figures for the arid, semi-arid and humid zones do not give a curve approaching anywhere to those obtained by Jenny (Fig. 1). On the other hand, when the points are joined irregular curves with several peaks and troughs are obtained. Hence the points on the graph are located but not joined. It is only in the case of values for the soils in the semi-arid zone that a tendency to approximate that of Jenny can perhaps be suspected.

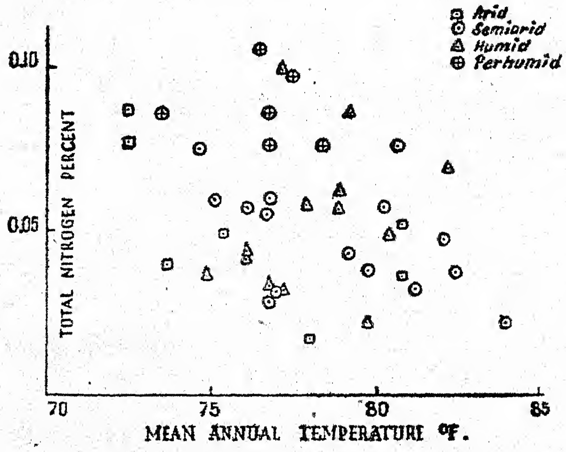

FIG. 1. Nitrogen content of surface soils in relation to temperature of different climatic zones

In regard to carbon and nitrogen ratios Russel [1937] and several others have observed that in temperate regions the ratio is usually about 10 to 12 and that there is no definite relationship between climate and carbon/nitrogen ratio. Jenny has made the passing observation that C/N ratio of the soil organic matter seems to become narrower with increasing temperatures.

McLean [1930] found that the C/N ratio of 50 British soils work at 10·2 $\pm$ 0·3 and form a normal frequency curve with a well defined maximum at 9·5 to 10·4 although the range is from 6·5 to 13·5. Our data on Indian soils has shown that many soils have ratios very much narrower than 10 (of the order of 4 and 5) and very much wider even going over 25. Leighty and Shorey [1930] have suggested the use of a mean C/N ratio of the profile in comparing various soil profiles. In the case of Indian soils, considering the C/N ratio of surface soils the maximum frequency distribution occurs between 11 and 13 and for the average C/N ratio of the profile the maximum frequency distribution lies between 10 and 12. The soils in the Punjab and Sind have generally narrower ratios compared to other places.

In the present study the soils included differ widely in their mechanical composition and texture. The effect of the textural differences on the C/N ratio of the sufrace soils and the average C/N ratio of the profiles has been examined. The data are presented in Table III.

TABLE III

Carbon and nitrogen ratios for the surface soils and average values for the profile and pH in the soils of different texture

Sandy loam				Silty loam				Loam				Clay loam			
Soil No.	pH	C/N Ratio		Soil No.	pH	C/N Ratio		Soil No.	pH	C/N Ratio		Soil No.	pH	C/N Ratio	
		Surface soil	Average			Surface soil	Average			Surface soil	Average			Surface soil	Average
10.A	7·31	11·4	10·7	11.A	7·69	6·4	8·7	13.A	7·34	15·7	12·5	54.S	8·75	10·7	15·3
9.A	7·59	7·5	4·3	1.A	7·90	10·7	11·3	3.S	8·21	5·4	3·9	48.S	7·97	19·3	19·5
33.S	6·65	13·8	10·8	2.A	7·14	11·2	6·0	18.H	8·0	6·7	6·5	55.S	8·47	18·5	20·8
34.S	7·15	10·9	9·7	7.S	7·88	5·1	4·8	56.H	7·06	14·0	12·5	32.S	7·51	22·9	20·7
50·S	7·05	11·2	11·8	8.P	6·93	11·0	6·9	28.H	7·16	12·2	12·7	25.S	7·91	12·7	12·4
60.S	7·30	9·7	8·2	36.P	5·91	9·0	9·4	26.H	6·46	11·6	10·5	31.S	7·78	12·8	11·1
57.H	7·91	11·1	11·2	..	..	..	..	38.P	5·69	13·0	10·6	52.S	8·05	23·6	21·8
58.H	6·05	11·2	7·6	..	..	..	..	51.P	4·66	11·8	11·2	..	..	..	..
59.H	7·28	14·1	16·8	..	..	..	..	..	..	..	..	49.H	7·17	7·5	10·0
19.H	7·69	11·1	10·7	..	..	..	..	..	..	..	..	30.H	6·68	10·7	11·3
39.P	5·69	13·8	7·5	..	..	..	..	..	..	..	..	24.H	7·31	12·1	16·3
35.P	4·26	12·4	9·6	..	..	..	..	..	..	..	..	27.H	6·41	13·4	11·1
37.P	4·84	7·5	4·9	..	..	..	..	..	..	..	..	29.H 22.H	7·51 6·57	10·7 13·7	17·1 10·0
43.P	3·74	10·4	6·7	..	..	..	..	..	..	..	..	40.H	6·39	8·1	8·8
Average	..	11·2	9·3	..	..	8·9	7·9	..	..	11·3	10·1	..	..	14·1	14·7

The letters after the soil number stand for as A = Arid ; S = semi-arid ; H = Humid P = Perhumid.

The average values indicate that the C/N ratio is 10·1 ± 1·2 for the sandy loam, silty loam and loamy soils. In the case of clay loam soils the C/N ratio is wide with a general average of 14·4. It is particularly interesting to note that 12 out of the 14 soils are black soils, the other two being a red soil of Ranchi and brownish black soil of Chinsura. Seven of the black soils are from the semi-arid region and their mean C/N ratio is 17·3 while the rest of the 7 soils are from the humid region with an average C/N ratio of 12·1.

McLean [1930] observed wide C/N ratios of the order 23·0 from Sudan clay. The C/N ratios of the semi-arid black soils of India are comparable with other tropical black soils in respect of the wide C/N ratios. The fact that the C/N ratio of the humid black soils is narrower compared to the semi-arid soils is indicative that moisture supply in heavy black soils appears to be a limiting factor in carbon oxidation. Anderson and Byers [1934] observed that wide divergence exists between the C/N ratio of the soil groups chernozem, prairie, podsol, grey brown and laterite. However, they found the most consistant ratio 9·0 (maximum 10 and minimum 7·5) in the chernozem group of soils. Thus it appears that the tropical black soils are not comparable to the chernozems in respect of their C/N ratios.

It is clear from the foregoing discussion of the data presented in the paper, that the general level of carbon and nitrogen in the uncultivated soils and profiles is low. Under normal agricultural practices the soils are liable to be depleted still further of their organic matter. The high mean annual temperatures of 24°C., 26°C., 25°C. and 24·4°C. in the arid, semi-arid, humid and per-humid regions respectively do not permit the building up of organic matter reserves. Thus the Indian soils require adequate and constant supply of organic matter and nitrogen in most cases is substantiated. The significance of these unusually wide and narrower C/N ratios in respect of nitrogen transformation processes and soil fertility as determined by crop yield will be discussed in a subsequent communication.

Summary

The organic carbon and nitrogen contents of 43 uncultivated soil profiles distributed all over India have been examined. The fluctuations in the carbon and nitrogen contents in the soil colour groups brown, black, red, grey and pink and calcareous soils, under arid, semi-arid, humid and per-humid regions have been discussed. The general level of the carbon and nitrogen in most of the soils is low. No correlation between climate and nitrogen content could be traced. The carbon/nitrogen ratios fluctuate widely from 5 to 25.

Barring the black soils of the semi-arid region the maximum frequency of the average C/N ratio occurs between 10 and 12. The semi-arid black soils show unusually wide C/N ratios. In view of the high mean annual temperatures in India, the need for adequate supply of organic matter and nitrogen to the soils is evident.

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Appendix

Carbon, nitrogen contents in successive horizons of soil profiles in arid region

(N. S. Quotitient below 100)

Depth. in inches	pH	CO_2	Organic carbon	Nitrogen Wet	Nitrogen Dry	CaCo₃	C/N
2. *Haripur Hazara* (Brown)							
0—12	7·14	3·82	0·971	0·087	0·074	4·68	11·2
12—24	7·16	2·22	0·417	0·105	0·084	5·06	4·4
24—36	7·04	2·10	0·521	0·100	0·088	4·77	5·5
36—48	7·03	1·15	0·374	0·100	0·080	2·63	4·2
48—60	7·15	1·63	0·365	0·100	0·084	3·70	4·0
9. *Lyallpur* (Brown)							
0—12	7·59	0·292	0·320	0·049	0·035	0·66	7·5
12—24	7·10	0·504	0·191	0·044	0·036	1·15	4·8
24—36	6·56	0·130	0·144	0·037	0·037	0·30	3·9
36—48	6·46	0·396	0·047	0·031	0·033	0·90	1·4
48—60	6·35	0·126	0·155	0·037	0·039	0·29	4·1
10. *Mianwali* (Grey and pink)							
0—12	7·31	2·80	0·457	0·040	0·040	6·36	11·4
12—24	7·51	2·11	0·239	0·024	0·024	4·80	10·0
24—36	7·67	2·85	0·281	0·024	0·024	6·48	11·7
36—48	7·91	4·64	0·223	0·027	0·022	10·55	8·3
48—60	7·94	0·24	0·369	0·030	0·030	0·55	12·3
13. *Mirpurkhas* (Grey and pink)							
0—12	7·34	4·34	0·569	0·036	0·032	9·86	15·8
12—24	7·48	4·13	0·343	0·032	0·032	0·43	10·7
24—36	7·63	3·63	0·368	0·028	0·028	8·25	13·1
36—48	7·64	2·79	0·339	0·030	0·030	6·35	11·3
48—60	7·81	2·54	0·353	0·034	0·032	5·77	10·7
1. *Peshawar* (Calcareous)							
0—12	7·90	8·02	0·856	0·077	0·083	18·20	10·7
12—24	8·37	8·58	0·403	0·030	0·035	19·50	12·4
24—36	8·35	8·27	0·336	0·033	0·028	18·80	11·1
36—48	8·94	7·87	0·327	0·034	0·031	17·93	10·1
48—60	8·57	8·58	0·347	0·031	0·026	19·50	12·3
11. *Sarkand* (Calcareous)							
0—12	7·69	5·22	0·325	0·052	0·050	11·90	6·4
12—24	7·80	4·81	0·237	0·037	0·037	10·93	7·4
24—36	7·23	3·70	0·470	0·033	0·033	8·40	14·1
36—48	7·24	4·88	0·432	0·035	0·040	11·10	11·4
48—60	7·27	5·06	0·221	0·039	0·041	11·50	5·0
12. *Karachi* (Calcareous)							
	7·14	9·88	0·305	0·017	0·017	22·45	17·9
	7·73	10·68	0·204	0·012	0·016	24·27	17·0
	7·52	11·36	0·208	0·018	0·018	25·80	11·6
	7·32	8·32	0·242	0·018	0·018	19·00	13·2
	7·40	10·12	0·115	0·018	0·018	23·00	8·8

APPENDIX—*contd.*

Carbon, nitrogen contents in successive horizons of soil profiles in semi-arid region

(N. S. Quotient 100-200)

Depth in inches	pH	CO_2	Organic carbon	Nitrogen Wet	Nitrogen Dry	$CaCO_3$	C/N
			25. Akola (Black)				
0—12	7·91	4·40	0·72	0·057	0·055	10·00	12·7
12—24	8·39	3·37	0·52	0·039	0·034	7·66	14·4
24—36	8·47	3·68	0·35	0·031	0·034	8·40	10·8
36—48	8·57	3·88	0·38	0·033	0·033	8·80	11·5
48—60	8·57	5·14	0·41	0·033	0·033	11·70	12·5
			31. Indore (Black)				
0—12	7·78	2·07	0·65	0·057	0·044	4·70	12·8
12—24	7·81	1·10	0·55	0·050	0·039	2·50	12·3
24—36	7·53	0·41	0·43	0·046	0·037	0·93	10·3
36—48	7·41	0·57	0·20	0·041	0·030	1·30	6·5
48—60	7·67	1·13	0·33	0·036	0·026	2·57	13·8
			32. Kharau (Black)				
0—12	7·51	1·31	1·26	0·055	0·055	2·98	22·9
12—24	7·45	2·63	0·663	0·034	0·034	6·00	19·5
24—36	7·38	2·92	0·300	0·037	0·037	6·64	21·6
36—48	7·60	2·71	0·729	0·036	0·036	6·16	20·3
48—60	7·63	2·50	0·693	0·036	0·036	5·68	19·3
			48. Padegaon (Black)				
0—12	7·97	4·32	0·83	0·043	0·037	9·80	19·3
12—24	8·19	3·07	0·86	0·042	0·034	7·00	20·5
24—36	8·03	3·61	0·86	0·040	0·033	8·20	21·5
36—48	7·98	3·39	0·68	0·036	0·026	7·70	19·0
48—60	7·55	4·30	0·54	0·031	0·022	9·80	17·4
			49. Surat (Black)				
0—12	7·17	0·55	0·57	0·076	0·057	1·25	7·5
12—24	7·21	0·18	0·58	0·058	0·044	0·41	10·0
24—36	7·22	0·25	0·51	0·055	0·041	0·57	9·3
36—48	7·14	0·27	0·49	0·048	0·040	0·62	10·3
48—60	7·09	0·25	0·37	0·029	0·028	0·57	12·8
			52. Koilpatti (Black)				
0—12	8·05	1·09	0·52	0·022	0·022	2·48	23·6
12—24	8·11	0·84	0·46	0·022	0·018	1·92	23·1
24—36	7·30	1·642	0·38	0·022	0·020	3·73	18·0
36—48	7·14	1·818	0·39	0·016	0·016	4·13	23·0
48—60	7·15	1·705	0·320	0·014	0·014	3·87	21·3
			54. Hagari (Black)				
0—12	8·75	3·124	0·503	0·047	0·031	7·10	10·7
12—24	8·60	4·092	0·544	0·044	0·031	9·3	14·7
24—36	8·01	3·413	0·553	0·039	0·030	7·76	15·4
36—48	7·95	2·372	0·358	0·022	0·022	5·43	16·5
48—60	8·49	2·304	0·338	0·018	0·022	7·70	17·9

APPENDIX—*contd.*

Carbon, nitrogen contents in successive horizons of soil profiles in semi-arid region

(N. S. Quotient 100-200)

Depth in inches	pH	CO_2	Organic carbon	Nitrogen		$CaCo_3$	C/N
				Wet	Dry		
			55. *Nandyal (Black)*				
0—12 . . .	8·47	1·734	0·685	0·036	0·038	3·94	18·5
12—24 . . .	8·58	1·232	0·560	0·026	0·026	2·80	21·5
24—36 . . .	8·71	1·492	0·429	0·026	0·022	3·40	17·9
36—48 . . .	9·16	1·965	0·488	0·024	0·024	4·47	20·3
48—60 . . .	9·15	2·104	0·572	0·024	0·022	4·78	26·0
			34. *Tabijii (Brown)*				
0—12 . . .	7·15	0·451	0·307	0·018	0·028	1·03	10·9
12—24 . . .	6·85	0·975	0·182	0·024	0·018	2·22	8·7
24—36 . . .	7·57	0·722	0·225	0·022	0·018	1·64	11·3
36—48 . . .	7·86	0·920	0·232	0·022	0·022	2·90	11·1
48—60 . . .	8·43	0·495	0·120	0·020	0·016	1·13	6·6
			50. *Coimbatore (Brown)*				
0—12 . . .	7·05	0·466	0·425	0·038	0·038	1·05	11·2
12—24 . . .	6·80	0·428	0·430	0·040	0·040	0·97	10·8
24—42 . . .	7·18	8·39	0·540	0·042	0·042	19·00	12·7
42—60 . . .	7·03	8·53	0·430	0·034	0·034	19·40	12·5
			57. *Anakpalli (Brown)*				
0—12 . . .	7·91	0·038	0·354	0·032	0·032	0·086	11·1
12—24 . . .	7·63	0·099	0·309	0·028	0·028	0·028	11·0
24—36 . . .	7·89	0·080	0·390	0·032	0·032	0·018	12·2
36—48 . . .	8·17	0·036	0·301	0·028	0·028	0·080	10·8
48—60 . . .	7·93	0·067	0·245	0·022	0·022	0·150	11·1
			60. *Delhi (Brown)*				
0—12 . . .	7·30	0·45	0·28	0·031	0·026	1·03	9·7
12—24 . . .	7·01	..	0·24	0·033	0·031	0·27	8·6
24—36 . . .	6·98	..	0·24	0·034	0·031	0·13	7·4
36—48 . . .	7·16	..	0·24	0·031	0·027	0·42	8·2
48—60 . . .	7·41	..	0·22	0·026	0·027	0·71	8·0
			3. *Lahore (Grey and pink)*				
0—12 . . .	8·21	0·844	0·311	0·059	0·055	1·92	5·4
12—24 . . .	7·66	0·633	0·269	0·052	0·050	1·44	5·3
24—36 . . .	7·52	0·494	0·150	0·053	0·055	1·12	2·7
36—48 . . .	8·07	0·847	0·170	0·053	0·048	1·92	3·0
48—60 . . .	8·12	2·072	0·129	0·039	0·039	4·71	3·3
			7. *Gurdaspur (Grey and pink)*				
0—12 . . .	7·88	0·543	0·372	0·074	0·072	1·23	5·1
12—24 . . .	7·38	0·167	0·305	0·056	0·055	0·38	5·5
24—36 . . .	7·11	0·076	0·294	0·059	0·055	0·17	5·1
36—48 . . .	7·05	0·152	0·253	0·057	0·057	0·35	4·4
48—60 . . .	7·13	0·057	0·227	0·055	0·055	0·13	4·1

APPENDIX—*contd.*

Carbon, nitrogen contents in successive horizons of soil profiles in arid region

(N. S. Quotient 100-200)

Depth. in inches	*p*H	CO_2	Organic carbon	Nitrogen Wet	Nitrogen Dry	$CaCO_3$	C/N
			33. *Makrera* (*Grey and pink*)				
0—12 . . .	6·65	0·78	0·82	0·060	0·058	1·88	13·8
12—24 . . .	6·75	0·09	0·45	0·036	0·037	0·21	12·6
24—36 . . .	6·80	0·07	0·44	0·034	0·034	0·16	12·4
36—48 . . .	6·98	7·78	0·23	0·028	0·027	17·70	8·5
48—60 . . .	7·00	6·45	0·13	0·021	0·019	14·66	6·7
			24. *Nagpur* (*Black*)				
0—12 . . .	7·31	1·20	0·595	0·049	0·046	2·73	12·1
12—24 . . .	7·51	0·32	0·596	0·040	0·040	0·74	14·9
24—36 . . .	7·38	0·33	0·681	0·034	0·033	0·74	19·9
36—48 . . .	7·54	0·27	0·582	0·033	0·033	0·61	18·0
48—60 . . .	8·04	2·40	0·483	0·030	0·030	5·45	16·5
			27. *Labhandi* (*Black*)				
0—12 . . .	6·41	0·058	0·90	0·057	0·060	0·13	13·4
12—24 . . .	6·47	0·011	0·60	0·059	0·044	0·03	11·7
24—36 . . .	6·68	0·013	0·44	0·057	0·046	0·03	8·5
36—48 . . .	7·68	0·034	0·54	0·049	0·041	0·08	11·8
48—60 . . .	7·75	0·055	0·43	0·460	0·031	0·12	10·3
			29. *Kheri-Adhartal* (*Black*)				
0—12 . . .	7·51	0·19	0·458	0·043	0·032	0·45	14·3
12—24 . . .	7·40	0·147	0·486	0·033	0·024	0·33	20·2
24—36 . . .	7·40	1·316	0·373	0·029	0·016	2·99	23·3
36—48 . . .	7·45	1·566	0·202	0·016	0·016	3·56	12·6
48—60 . . .	7·31	1·06	0·243	0·016	0·016	2·41	15·2
			30. *Powerkhera* (*Black*)				
0—12 . . .	6·68	0·22	0·62	0·058	0·050	0·50	10·7
12—24 . . .	6·99	0·34	0·54	0·049	0·039	0·77	11·2
24—36 . . .	7·17	0·19	0·54	0·047	0·038	0·43	11·4
36—48 . . .	7·23	0·25	0·55	0·045	0·038	0·57	12·0
48—60 . . .	7·46	0·37	0·43	0·039	0·035	0·84	11·2
			56. *Samalkot* (*Black*)				
0—12 . . .	7·06	0·218	0·965	0·069	0·069	0·495	14·3
12—24 . . .	8·52	0·256	0·823	0·070	0·070	0·584	11·7
24—36 . . .	8·78	0·223	0·682	0·059	0·059	0·507	11·6
			40. *Chinsura* (*Brownish black*)				
0—12 . . .	6·39	..	0·69	0·086	0·067	..	8·1
12—24 . . .	7·31	..	0·63	0·061	0·045	..	10·3
24—36 . . .	7·70	..	0·66	0·052	0·038	..	12·5
36—48 . . .	7·79	..	0·41	0·051	0·038	..	8·1
48—60 . . .	7·74	..	0·26	0·051	0·035	..	5·0

APPENDIX—*contd.*

Carbon, nitrogen contents in successive horizons of soil profiles in arid nitrogen

(N. S. Quotient 100-200)

Depth in inches	pH	CO_2	Organic carbon	Nitrogen		$CaCO_3$	C/N
				Wet	Dry		
18. *Shahjahanpur* (*Brown*)							
0—12 . . .	8·00	..	0·22	0·032	0·032	..	6·7
12—24 . . .	7·68	..	0·34	0·042	0·032	..	8·0
24—36 . . .	7·33	..	0·31	0·038	0·036	..	8·1
36—48 . . .	7·27	..	0·20	0·040	0·041	..	4·9
48—60 . . .	7·21	..	0·17	0·033	0·039	..	5·0
26. *Waraseoni* (*Greyish yellow*)							
0—12 . . .	6·46	0·103	0·487	0·042	0·038	0·234	12·2
12—24 . . .	6·95	0·032	0·402	0·037	0·033	0·073	11·5
24—36 . . .	7·95	0·109	0·357	0·033	0·022	0·248	13·2
36—48 . . .	7·56	0·172	0·179	0·033	0·022	0·390	6·6
48—60 . . .	7·09	0·105	0·205	0·031	0·018	0·240	8·8
22. *Ranchi* (*Red*)							
0—12 . . .	6·57	..	0·52	0·036	0·039	..	13·7
12—24 . . .	6·50	..	0·30	0·035	0·033	..	8·7
24—36 . . .	6·81	..	0·21	0·034	0·037	..	5·9
36—48 . . .	7·14	0·044	0·30	0·035	0·034	0·10	8·7
48—60 . . .	7·43	0·069	0·40	0·029	0·033	0·16	13·1
28. *Chandkuhuri* (*Red*)							
0—5 . . .	7·16	0·17	0·86	0·062	0·062	0·40	14·0
5—16 . . .	6·54	0·07	1·05	0·082	0·080	0·16	12·9
16—28 . . .	6·68	0·13	0·76	0·066	0·060	0·30	11·5
28—40 . . .	7·30	0·09	0·38	0·042	0·040	0·20	9·3
40—52 . . .	6·87	0·07	0·29	0·035	0·032	0·16	8·6
52—60 . . .	6·84	0·10	0·21	0·028	0·028	0·23	7·4
58. *Berhampur* (*Grey and pink*)							
0—12 . . .	6·05	0·025	0·247	0·022	0·022	0·06	11·2
12—24 . . .	6·12	..	0·167	0·022	0·022	..	7·6
24—36 . . .	6·93	0·042	0·133	0·022	0·022	0·10	6·0
36—48 . . .	7·08	0·032	0·142	0·020	0·022	0·07	7·0
48—60 . . .	7·13	0·073	0·118	0·020	0·020	0·17	6·0
19. *Padrauna* (*Calcareous*)							
0—12 . . .	7·69	16·45	1·10	0·099	0·097	37·40	11·1
12—24 . . .	7·88	21·56	0·23	0·027	0·025	49·00	8·9
24—36 . . .	7·93	22·77	0·19	0·015	0·015	51·75	11·9
36—48 . . .	7·96	23·10	0·15	0·015	0·013	52·50	10·4
48—60 . . .	7·83	24·53	0·17	0·013	0·015	55·75	11·4
59. *Pusa* (*Calcareous*)							
0—12 . . .	7·28	15·84	0·46	0·033	0·030	35·99	14·1
12—24 . . .	7·44	17·45	0·49	0·033	0·035	39·66	14·2
24—36 . . .	7·21	17·88	0·35	0·020	0·020	40·53	17·5
36—48 . . .	7·28	19·65	0·36	0·020	0·020	44·67	18·8
48—60 . . .	7·45	21·06	0·37	0·018	0·018	47·86	19·5

APPENDIX—*concld.*

Carbon. nitrogen contents in successive horizons of soil profiles in per-humid region

(N. S. Quotient 400 and above)

Depth. in inches	pH	CO_2	Organic carbon	Nitrogen Wet	Nitrogen Dry	$CaCO_3$	C/N
			8. *Kangra* (Brown)				
0—12 . . .	6·93	..	1·196	0·112	0·105	..	11·1
12—24 . . .	6·77	..	0·746	0·075	0·074	..	10·0
24—36 . . .	6·77	..	0·327	0·050	0·046	..	6·8
36—48 . . .	6·81	..	0·206	0·047	0·036	..	5·0
48—60 . . .	6·38	..	0·059	0·031	0·32	..	1·8
			35. *Jorhat* (Brown)				
0—12 . . .	4·26	..	1·04	0·086	0·683	..	12·4
12—24 . . .	4·10	..	0·51	0·042	0·039	..	12·6
24—36 . . .	4·05	..	0·16	0·030	0·031	..	5·2
36—48 . . .	4·03	..	0·25	0·024	0·024	..	10·0
48—60 . . .	4·10	..	0·17	0·020	0·021	..	8·0
			36. *Karimganj* (Brown)				
0—12 . . .	5·81	..	0·777	0·086	0·086	..	9·3
12—24 . . .	5·88	..	0·561	0·070	0·070	..	8·0
24—36 . . .	5·80	..	0·580	0·048	0·048	..	12·3
36—48 . . .	5·91	..	0·523	0·048	0·048	..	10·9
48—60 . . .	6·22	..	0·325	0·048	0·048	..	6·8
			37. *Sylhet* (Brown)				
0—12 . . .	4·84	..	0·57	0·076	0·076	..	7·5
12—24 . . .	4·45	..	0·76	0·074	0·074	..	10·3
24—36 . . .	4·17	..	0·15	0·068	0·068	..	2·3
36—48 . . .	3·94	..	0·15	0·071	0·071	..	2·2
48—60 . . .	4·14	..	0·13	0·061	0·061	..	2·2
			38. *Dacca* (Greyish brown)				
0—12 . . .	5·69	..	0·982	0·076	0·076	..	13·0
12—24 . . .	4·64	..	0·497	0·056	0·052	..	9·2
24—36 . . .	4·74	..	0·436	0·044	0·042	..	10·1
36—48 . . .	4·94	..	0·389	0·032	0·032	..	12·1
48—60 . . .	5·24	..	0·243	0·030	0·028	..	8·4
			43. *Sirsi* (Red)				
0—12 . . .	3·78	..	1·00	0·097	0·097	..	10·4
12—24 . . .	4·17	..	0·43	0·057	0·057	..	7·5
24—36 . . .	4·20	..	0·27	0·042	0·041	..	6·6
36—48 . . .	4·12	..	0·17	0·042	0·043	..	4·1
48—60 . . .	4·14	..	0·20	0·039	0·040	..	5·1
			51. *Taliparamba* (Red)				
0—12 . . .	4·66	..	2·078	0·178	0·178	..	11·8
12—24 . . .	4·45	..	1·277	0·098	0·098	..	13·0
24—36 . . .	4·37	..	0·570	0·056	0·054	..	10·4
36—48 . . .	4·33	..	0·552	0·050	0·052	..	10·8
48—60 . . .	4·16	..	0·33	0·034	0·034	..	9·8
			39. *Rangpur* (Grey and pink)				
0—12 . . .	5·69	..	1·43	0·105	0·102	..	13·8
12—24 . . .	5·83	..	0·63	0·049	0·049	..	12·9
24—36 . . .	5·96	..	0·09	0·017	0·012	..	6·5
36—48 . . .	5·97	..	0·02	0·009	0·009	..	2·3
48—60 . . .	6·06	..	0·02	0·009	0·009	..	1·9

KANKAR COMPOSITION AS AN INDEX OF THE NATURE OF SOIL PROFILE*

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(With Plates XXII and XXIII and one text-figure)

TO any one who has had an opportunity of studying the soil profiles of Indo-Gangetic alluvium, and more particularly the ' Bhangar ' i.e. the older alluvium the presence of *kankar* nodules or concretions of varying size, shape and colour must present a characteristic feature. Similar variations in shape and size of lime nodules occurring in Tshernozems (Russia) have been reported by Kassatkin and Krasyuk [1917] †.

An examination of a number of soil profiles in the South East Punjab indicated that the size, shape and colour of *kankar* and other concretions had some relation to the nature of soil profiles. The process of leaching by rain water and attendant *kankar* formation is not likely to affect $CaCO_3$ only, but depending on the prevailing conditions, other constituents, e.g. magnesia, iron, manganese phosphorus, etc., may also be affected more or less.

The nature of climate and of the soil profile determines the conditions of leaching, and thus the nature and amount of constituents mobilized should bear some relationship with the nature of climate and soil profile. Further, these mobilized constituents will get deposited in the profile in its lower layers, because of a change in soil properties. This deposition may occur either along with $CaCO_3$ in the *kankar* concretions or as separate concretions like ferromanganiferrous ones, or rarely even as limy ferruginous concretions. For example, under conditions of lateritic weathering silica is mobilized and may be deposited in the lower layers of soil with high $CaCO_3$ and comparatively lower *p*H, whereas under conditions of podzolic weathering, more particularly under conditions of poor aeration, sesquioxides are affected. It follows that *kankar* from soil profiles of varied nature might vary in composition accordingly, and that its composition would bear some relationship to the nature of soil profile. This paper reports the results of an investigation carried out to elucidate these points.

Very little work has been done on *kankar* composition so far ; while the relationship of its composition to nature of the soil profile has not been studied at all. However, a lot of work on composition and relation with nature of soil profiles for secondary formations in Podzols (i.e., ortsteins, ferruginous concretions) has been reported, notably by Bennet and Allison [1928], Winters [1938], Drosdoff and Nikiforov and Beater [1940]. Composition of *kankar* has been given by Oldham [1891], in the Annual Report of the Dry Farming Research Station, Sholapur (1935), by Gillam [1937], and Beater [1940]. Wadia and co-workers [1935] have given a detailed bibliography on *kankar* composition. etc.

The present work comprised a study of the differences in chemical composition and physical properties as affected by soil stage or phase of *kankar* soil profile, climate, soil type, texture of the mother soil, depth at which it occurs in the profile and size of the *kankar*.

MATERIALS AND METHODS

Kankar samples were collected from the typical *kankar* soil profiles from Rohtak district, from *kankar* profiles from Lyallpur, Ferozepur, Beas and Jullundur in the Punjab, from Kankather and Deoria in the United Provinces, from black cotton soils from Sholapur (Bombay Presidency) and Indore (Central India), from Bahrein (Persian Gulf), and from a number of other sites.

Concretions and nodules retained on 1 mm. sieve were well soaked with water to loosen the adhering soil and washed till thoroughly clean. These were finally washed with distilled water, dried in the sun, weighed and reported on total weight of air dry soil.

*Part of a thesis submitted for partial fulfilment for the degree of M.Sc. by the junior author

†Cited by Joffe, J. S. (1936). *Pedology*, 53

1. *Physical properties*

(i) *Size distribution.* It was determined by sieving the samples through sieves of square holes of $1\frac{1}{2}$ in., $\frac{5}{8}$ in., $\frac{1}{4}$ in. and round holes of 3, 2 and 1 mm. diameter, and weighing the fractions retained on each.

(ii) *Real density.* It was determined by weighing the unpounded sample in air and under benzene; before weighing in benzene, the sample was left under benzene in a vacuum desiccator to let the liquid penetrate. The results were checked by using a powdered sample and the usual specific gravity bottle.

(iii) *Apparent density.* A method for determining apparent density involving the use of a thick lubricating oil (C oil or gear oil) was used for the purpose. The determination was made on the sample used for real density after benzene had completely volatilized.

(iv) *Moh's hardness number.* It was determined as described by Merril [1897].

(v) *pH value.* It was determined by glass electrode.

2. *Chemical properties*

(i) *HCL extract analysis.* The Agricultural Education Associations method [Wright, 1939] was used. Additional quantity of the acid required to decompose carbonates was allowed for.

(ii) *Ultimate analysis.* The A.O.A.C. [1940] method was followed, excepting that sodium carbonate used was about half the quantity of *kankar* samples taken, as given by Scott [1925] for cement analysis.

(iii) *Free sesquioxides.* These were determined by Drosdoff and Truog's method, as described by Ray Chaudhri and Sulaiman [1940].

EXPERIMENTAL

A. *Effect of stage of soil profile development.* During the collection of the *kankar* samples, it was noted that some of them were soft, whereas others very hard. Accordingly hardness number and compactness were determined in samples of unpounded *kankar* from the different stages* of soil profile development. As a measure of compactness, pore space was calculated from data of real and apparent density. The results are given in Table I.

TABLE I

Physical properties of kankar

Property					*Total*	*Average*
Young profiles	IIIA.	IIIB.				
Hardness	1·0	0·5			1·5	0·75
Pore space	13·85	25·20			39·05	19·52
Immature profiles	IB(i)	IB(v)	IC(i)	IC(iv)		
Hardness	2·0	3·0	4·0	6·0	15·0	3·8
Pore space	10·34	10·82	7·76	21·24	50·18	12·55
Semi-mature profiles	IB(ii)	IB(iv)				
Hardness	7·0	7·0			14·0	7·0
Pore space	5·52	2·08			7·60	3·80
Mature profiles	IA(i)	IC(iii)	IE			
Hardness	6·5	7·5	7·00		21·0	7·0
Pore space	2·05	4·26	4·48		10·79	3·60

*Stage of development of soil profile refers to the amount of leaching, as determined by distribution of $CaCO_3$ in the profile; young profile is that in which practically no leaching is perceptible, Immature shows depletion of $CaCO_3$ from horizons overlying *kankar*. In the case of semi-mature profile, the horizons overlying *kankar* have almost lost the whole of $CaCO_3$, whereas the mature profile is absolutely devoid of $CaCO_3$ till *kankar* appears.

It may be seen that *kankar* becomes harder and less porous till the semi-mature stage of soil profile is reached, i.e. when the horizons overlying *kankar* horizon have lost $CaCO_3$ completely. No further change is noted in samples from the later stages of soil profile. When we examine the individual figures we find that sample No. IC (iv), though bearing large pore space (21·24) has a hardness number of 6·0. This may be explained due to its being dolomitic in character.

To find out the composition of these different types of *kankar*, both ultimate analysis and hydrochloric acid extract analysis were carried out and the data for typical samples are presented in Table II.

TABLE II

Ultimate analysis of typical kankar *samples.*

Percentage on air dry sample

Stage of soil profile	Depth of occurrence	Loss on ignition	SiO_2	Fe_2O_3	P_2O_5	Al_2O_3 and TiO_2	Mn_2O_3	CaO	MgO
Immature	14-29 in.	27·19	29·84	3·65	..	7·95	0·04	28·52	1·47
Semi-mature	14-20 in.	22·71	30·10	2·17	..	9·73	0·10	30·54	2·58
Mature	64-69 in.	26·18	28·48	3·35	..	6·60	0·10	31·02	2·16
Degraded*	30-42 in.	7·59	55·27	19·27	0·84	11·64	2·18	0·75	0·65

Hydrochloric acid extract analysis

	Moisture	CO_2	Insoluble residue	Soluble silica	Fe_2O_3	P_2O_5	Al_2O_3	Mn_2O_3	CaO	MgO	K_2O	Na_2O	$CaCO_3$† Equivalent	$CaCO_3$† Calculated
Immature	(14-29 in.)0·25	23·73	36·77	0·27	2·44	0·07	4·67	0·04	28·34	1·82	0·25	0·43	53·95	50·60
Semi-mature	(14-20 in.)·028	22·71	38·06	0·31	2·32	0·07	3·33	0·10	31·36	1·64	0·25	0·35	51·65	55·92
Mature	(64-69 in.)0·48	24·02	33·91	0·85	2·72	0·06	2·69	0·10	29·99	2·01	0·22	N.D.	54·61	53·55
Degraded	(30-42 in.)2·45	*Nil*	65·81	0·18	15·92	0·84	8·08	1·96	1·12	1·38	0·58	0·39	*Nil*	2·00

*The samples are in fact ferro-manganiferrous concretions, and cannot be called *kankar*. These have been included to serve as a contrast in composition of the two types of secondary formations.

†Equivalent is that computed from percentage CO_2 of the sample assuming that the whole of it has been derived from $CaCO_3$. Calculated figures have been worked out from percentage CaO, assuming that all of it is present as carbonate.

It may be noted that the different types do not show any systematic change. The mother soil‡ in the case of these samples varied from light loam to heavy loam. Since *kankar* has been formed by redeposition of $CaCO_3$, etc., with the mother soil, the nature of the mother soil would affect its composition a great deal. It was thus felt necessary to analyse the mother soil for the samples of *kankar* studied.

For a comparison of composition of sample from the different stages of soil profile development on a uniform basis, the effect of varied nature of mother soil should be accounted for. Since *kankar* has been formed under conditions of abundant supply of $CaCO_3$, there are very little chances of SiO_2 being mobilized and its being deposited in the lower layers. This is also the opinion of Sigmond [1938] and Merril [1897], who maintain that in the formation of soil from limestone rock, silica is not lost. It was thus felt that the amount of mother soil used in the formation of *kankar* samples could be calculated from SiO_2 content of the two by the following formula :

$$\text{Percentage of mother soil in } kankar = \frac{\text{Percentage of } SiO_2 \text{ in } kankar}{\text{Percentage of } SiO_2 \text{ in mother soil}} \times 100.$$

Thus if the analysis of *kankar* and mother soil is known, the constituents other than those derived from mother soil that go to form various samples can be calculated by subtracting the constituents supplied by the mother soil from the percentage composition of *kankar*. The detailed results are not given, but the balance of constituents thus calculated is given for all the samples in Table III.

‡This term has been used after Bennet and Allison [1928] to designate the soil in which *kankar* was found embedded.

TABLE III

Balance of kankar *constituents. Based on SiO_2 percentage of* kankar *and mother soil*

Percentage of air dry sample

Serial No.	Profile	Stage	Moisture	CO_2	Insoluble residue	Fe_2O_3	Al_2O_3	P_2O_5	Mn_2O_3	CaO	MgO	K_2O	Na_2O
1	IA (iii) .	Immature .	—0·27	22·73	0·0	1·47	*Nil*	0·01	0·01	29·65	..	0·25	..
2	IB (i) .	.. .	—0·37	19·17	0·0	0·23	1·54	0·003	0·02	23·11	0·20	..	..
3	IB (v) .	.. .	—0·08	18·83	0·0	1·69	0·[illegible]4	0·003	0·01	23·00	1·18	0·02	0·11
4	IC (iv) .	.. .	..	18·48	0·0	0·76	1·48	0·024	0·03	13·60	8·55	0·22	0·05
5	IB (ii) .	Semi-mature	..	21·57	0·0	0·94	2·64	0·000	..	28·18	2·00	..	..
6	ID . .	..	0·00	23·48	0·0	0·90	0·31	0·026	..	30·63	0·69	0·07	0·09
7	IB (iv) .	.. .	0·05	21·08	0·0	0·59	1·[illegible]3	..	..	27·37	..	..	..
8	IA (i) .	Mature .	0·19	23·07	0·0	1·45	1·04	0·029	0·08	28·98	1·77	—0·15	N.D.
9	IA (ii) .	.. .	—0·28	31·00	0·0	1·08	0·[illegible]2	0·014	0·12	43·15	..	0·07	..
10	IA (iv) .	.. .	—0·32	25·22	0·0	1·02	1·54	0·074	0·10	33·29	1·08	0·09	0·06
11	IE . .	.. .	0·09	31·60	0·0	1·12	0·35	..	..	40·37	0·67	..	..

It may be noted that in addition to the obvious accumulation of carbonates, calcium and magnesium in all the samples, accumulation of iron and phosphate tends to increase with maturity of the profile, but the evidence is in no way conclusive.

B. *Effect of climate and soil type on composition of* kankar. The role of climate in the formation of soils is now well recognized. Glinka [1914] has mentioned the formation of a similar soil from parent materials differing as widely as loess and granite. It was felt that since *kankar* is a secondary formation formed in the soil, differences in climate would affect its composition. Samples of *kankar* from different soils and climates were analysed and the data together with that reported in literature are given in Table IV. As a criterion of climate. Meyer's N : S quotient [Singmond, 1938] is given in the first column.

The effect of the soil type is clearly seen in Table IV. One of the Bahrein samples contains 0·48 per cent SO_3 as gypsum, while the other as much as 19·1 per cent. In contrast with this sample, the sample from a slightly gypseous profile (percentage of $CaSO_4$=1·8) from Rohtak does not contain any gypsum, presumably because of less dry climate (N : S quotient 13 and 47 respectively).

TABLE IV

Composition of kankar *(lime concretion) samples from different climate and soil types*

Percentage on air dry samples

Locality	N. S. Quotient	Moisture	CO_2	Insoluble residue	Fe_2O_3	P_2O_5	Al_2O_3 TiO_3	Mn_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	$CaCO_3$ Equivalent	$CaCO_3$ Calculated
Bahrein (*a*)	13·3	0·86	31·27	16·16	1·77	0·055	1·83	0·03	42·47	1·69	0·40	0·30	0·48	71·08	75·84
Bahrein (*b*)	13·3	N.D.	14·81	11·84	0·32	0·023	0·82	..	33·59	0·73	0·30	2·76	19·13	33·66	59·98
[1]Lyallpur	40·6	0·55	29·60	19·11	4·18	..	5·96	0·11	37·05	2·44	0·42	0·23	*nil*	67·23	66·16
Ferozepur	...	0·27	26·19	32·29	1·65	0·060	1·85	..	34·36	1·14	0·31	0·09	,,	59·53	61·37
Rohtak	46·9	0·48	24·02	33·91	2·72	0·060	2·69	..	29·99	2·01	0·22	N.D.	,,	54·61	53·55
[1] Do.	46·9	..	..	28·48	3·35	...	6·60	0·10	31·02	2·16	0·52	0·23	,,	..	..
Dolomitic	46·9	0·39	20·36	44·09	2·64	0·060	4·45	0·04	15·16	10·30	0·33	0·45	,,	46·27	27·07
Beas	..	0·75	31·91	19·08	1·85	..	2·59	0·03	40·87	1·10	..	..	,,	72·50	..
[1]Jullundur	..	0·89	22·76	25·40	9·44	..	2·84	0·22	29·49	1·35	..	..	,,	51·75	52·67
Deoria (U. P.)	192·4	0·57	24·58	29·22	2·13	0·04	0·04	0·23	32·65	2·03	0·44	0·23	,,	55·90	58·33
Indore (white)	96·4	..	31·02	15·84	2·02	0·033	2·82	0·41	40·08	0·89	0·42	0·36	,,	70·50	71·59
.. (black)	96·4	1·26	35·64	9·48	1·96	0·033	2·58	0·41	46·31	0·81	0·26	0·15	,,	81·00	82·74
Bijapur	57·0	..	N.D.	7·06	15·97	0·08	5·97	N.D.	36·63	0·29	0·38	N.D.	N.D.	..	65·40
Moody and Crofton Series (U. S. A.).	..	..	..	16·0	..	..	..	..	44·9	1·40	..	..	..	83·7	81·0[illegible]
[1] Mt. Edgecombe (S. Africa) .	225·4	1·44	23·0	27·76	5·00	0·06	1·95	0·09	31·45	1·54	0·58	0·22	..	52·3	56·1
[1] Matanzas (Cuba) . .	250·0	1·65	1·22	15·60	46·38	0·20	18·13	0·85	2·79	0·46	0·26	1·65	..	2·77	4·98

[1] Results of fusion analysis. For purposes of comparison of HCl extract and fusion analysis, results for Rohtak samples by the two methods are given.

The other two Rohtak samples coming from calcareous and dolomitic profiles respectively show a corresponding difference in their CaO and MgO content. The dolomitic sample contains as much

as 10·30 per cent MgO as compared to 2·16 per cent for limy sample. The limy ferruginous sample from black cotton tract (Bijapur) has a high iron content (16 per cent Fe_2O_3) and also of $CaCO_3$ [65 per cent and very little of SiO_2 (7 per cent)], whereas the Indore limy samples (both black and white) are very poor in iron and silica and much richer in carbonates (85 per cent). The sample from Moody and Crofton series (U. S. A.) contains much more of carbonates and presumably very little of iron. The Mt. Edgecombe sample, though similar to the Rohtak sample in many respects contains much less of alumina. Lastly the sample (Perdigon as Bennet and Allison call it) from Cuba is seen to be highly rich in iron (46·4 per cent Fe_2O_3) but very poor in silica (15·6 per cent) and carbonates (1·2 per cent). In fact the mother soil is richer in carbonates (3·6 per cent) than the concretions.

In general it may be said that as N : S quotient increases, percentage of Fe_2O_3 in concretions increases.

C. *Effect of texture of the mother soil.* While taking *kankar* samples from soil profiles of different texture, a great difference in size and shape was noted. Determination of the size distribution of a few *kankar* samples was carried out and the data are presented in Table V.

TABLE V

Determination of the size distribution of kankar

Profile	Percentage in mother soil		Percentage of *kankar* sample retained on sieves						Calculated specific surface
	Clay	Silt	$1\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{1}{4}$ in.	3 mm.	2 mm.	1 mm.	
IH Deoria	11·0	15·2	47·5	14·8	18·9	16·2	2·0	0·5	167·8
IF Jullundur	13·7	42·7	..	37·4	37·9	22·9	2·5	0·4	246·3
IB IV Rohtak	11·0	30·8	13·0	54·0	25·4	7·5	0·1	..	135·1
IA (i) Do.	6·5	20·5	..	54·5	47·0	2·5	..	..	151·5
IB (ii) Do.	10·7	24·0	..	22·3	51·1	23·2	1·0	2·4	277·9
Ib (i) Do.	17·2	32·5	..	3·3	74·5	21·4	0·3	0·5	266·2
IC Lyallpur	32·1	28·0	..	..	..	71·8	15·2	13·0	676·8
IA (ii) Rohtak	30·0	52·0	..	..	19·8	74·8	4·8	0·7	455·2

In Table V specific surface per 100 gm. of *kankar* sample is given in the last column, and provides a single value for the size distribution. It is low in the case of preponderantly coarse samples, and high in the case of small sized samples. It may be seen that specific surface is low in case of samples from light textured mother soils and vice versa. Correlation coefficient (r) of specific surface with clay per cent in mother soil comes to + 0·929 (expected value at 1 per cent =0·765), indicating very high relationship.

Samples from heavy textured mother soil are conchoidal, elliptical to spherical in shape and no marked change of shape with increase in size is noted ; whereas samples from light textured mother soils were found to present a great deal of difference in shape with increase in size (Plate XXII, fig. 2). The large pieces are much more angular (locally called '*bichhwa*' or scorpion type because of their appendages) and have many holes permeating them (Plate XXII, fig. 1).

It was felt that the difference in texture of the mother soil would affect the composition of *kankar*. It may be that soil particles of different texture require different quantities of calcium carbonate for their being cemented together. Since percentage of sesquioxides, P_2O_5, manganese, etc. in

Fig. 1. *Kankar* samples (Scorpion type) of different sizes. It is seen that the larger pieces have holes permeating them.

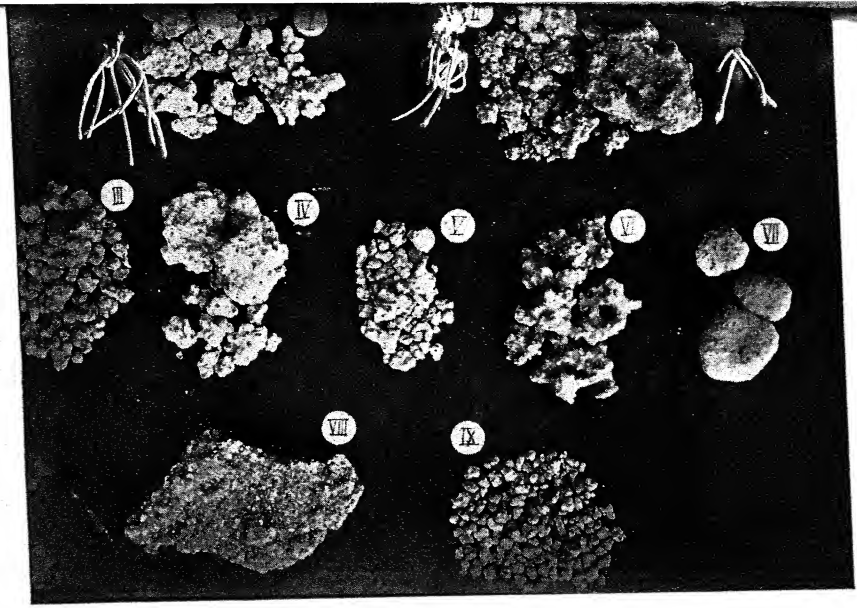

Fig. 2. Different samples of *kankar* (lime concretions) I-IB (i); II-IF (i); III-IE; IV-IH; V-IA (ii); VI-IA (i); VII-IIIA (i); VIII-IE (ii); IX-IG.

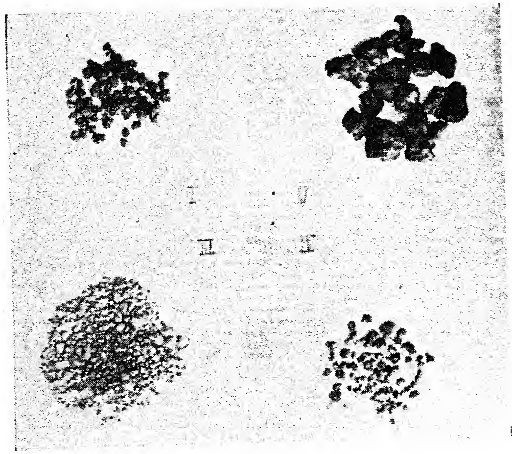

Fig. 3. Limy ferruginous and ferro manganiferrous concretions $\times \frac{1}{4}$ approximately

I—Fe Mn concretions	III—Ca Fe concretions
II— do	IV— do

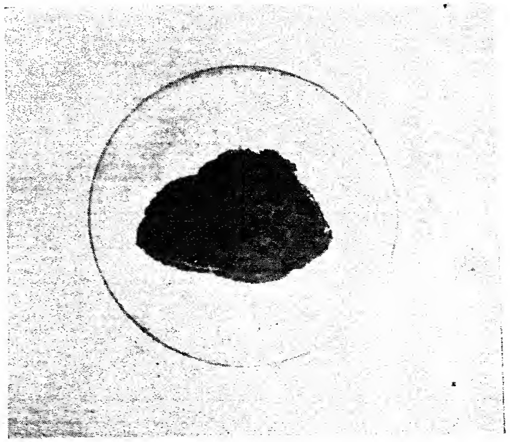

Fig. 4. A piece of mature *Bhata* (slab) type of *kankar* from Kankather (U.P.) showing the deposition of free iron and manganese as spherical deposits $\times \frac{1}{4}$ approximately.

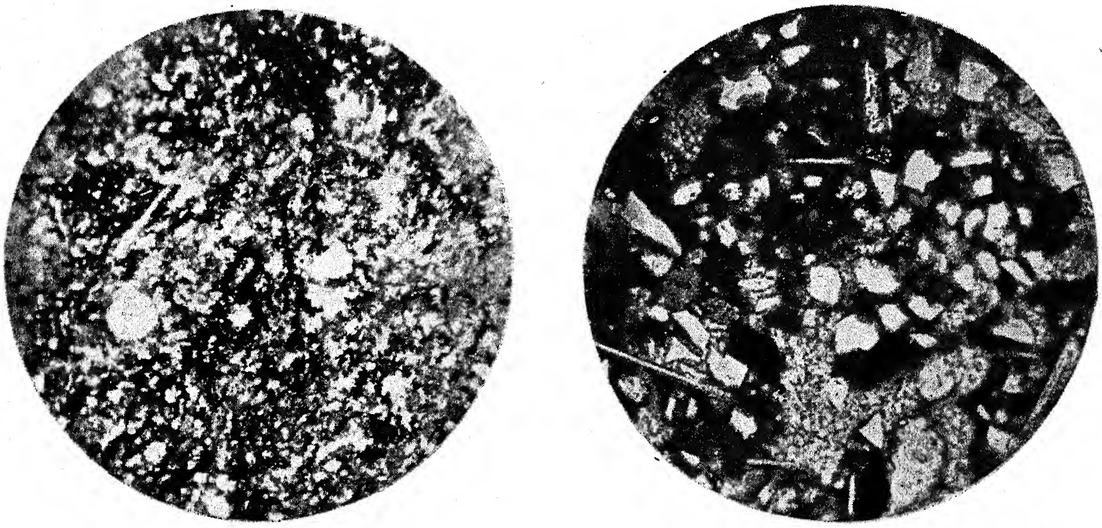

FIG. 1. Microphotographs

1K [IA(i)—Mature] × 62 7K [IB (i)—Immature] × 57

Q—Quartz ; Ca—Calcite ; Mu—Muscovite ; Bi—Oxidized Biotite

clay—Ca——Clay-calcite

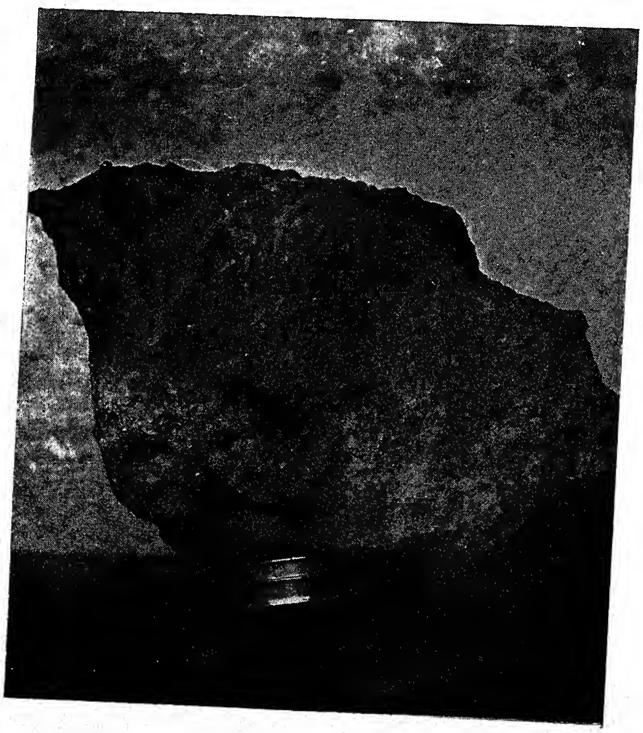

FIG. 2. *Bhata* (slab) type of *kankar* × $\frac{1}{4}$

kankar are greatly affected by climate, maturity of soil profile, etc., it was thought proper to compare samples from the same climate. The results for such a comparison are presented in Table VI.

TABLE VI

Effect of texture of mother soil on composition of kankar

Percentage on air dry sample

Locality	Texture of mother soil		Percentage of mother soil	Percentage of *kankar*			
	clay	silt		SiO_2	Fe_2O_3	Al_2O_3	$CaCO_3$
1. Beas (Dist. Amritsar).	2·0	2·5	46·3	36·7	3·7	8·0	48·7
2. Rohtak . .	6·5	20·5	38·7	28·5	3·4	6·6	51·6
3. Rohtak . .	10·7	24·0	46·3	30·1	3·2	7·7	51·6
4. Rohtak . .	25·9	37·2	35·3	23·2	4·0	5·8	60·0
5. Rohtak . .	30·0	52·5	18·4	12·3	1·9	4·6	73·4
6. Beas . . .	27·6	38·8	20·6	14·0	4·0	5·4	72·5

A progressive increase of carbonates with increase in clay content of the mother soil is noted. Correspondingly percentage SiO_2 content of *kankar* goes on decreasing with the heaviness of texture of the mother soil. Percentage of mother soil, in general, is low in samples from heavy textured mother soils and high in samples from light textured mother soil. The figures for iron and alumina do not warrant any general remarks. Correlation coefficient (r) of percentage of $CaCO_3$ in *kankar* samples with clay content of the mother soil works out to + 0·842 indicating very high significance, expected value at 1 per cent being 0·699.

D. *Effect of size.* To study how variation in size of *kankar* affected its composition, different fractions (above $1\frac{1}{2}$ in., $\frac{5}{8}$ in., $\frac{1}{4}$ in., 3 mm. and that below 2 mm.) of two samples of *kankar* from profile IB and IA were analysed for their HCl extract. The results are subjoined in Table VII.

TABLE VII

Effect of size on kankar *composition*

P-IB (iv)	Moisture	Insoluble residue	CO_2	Fe_2O_3	Al_2O_3	CaO
Above $1\frac{1}{2}$ in.	0·36	38·44	24·34	2·06	4·56	28·84
$1\frac{1}{2}$-$\frac{5}{8}$ in.	0·36	40·56	22·08	2·16	4·74	28·00
$\frac{5}{8}$-$\frac{1}{4}$ in.	0·55	36·58	23·16	1·99	4·85	29·95
$\frac{1}{4}$in.-3 mm.	0·36	34·24	24·32	2·13	4·61	32·48
Below 2mm.	..	..	19·07	..	..	..
P-IA (ii)						
Above $\frac{5}{8}$ in.	N.D.	40·23	21·62	1·67	4·45	28·55
$\frac{5}{8}$-$\frac{1}{4}$ in.	..	41·07	21·62	1·36	4·48	29·39
$\frac{1}{4}$in.-3 mm.	..	42·14	21·23	1·81	3·57	29·11
Below 2 mm.	..	..	18·34	..	..	..

It may be noted that the different fractions, except that for below 2 mm., do not differ materially in composition. Fraction below 2 mm. was obtained by sieving the powdered soil under water on a 100 mash sieve, and cleaning the sample retained on the sieve from coarse sand and mica. The low carbonate content of this fraction is possibly due to contamination with sand.

E. *Nutritive aspect of* kankar. That plant roots excrete carbonic acid, and under conditions of poor aeration even organic acids, etc., is well known [Miller, 1939]. In view of the fact that *kankar* contains appreciable quantities of nutrients (0·03—0·09 per cent P_2O_5 and 0·15 to 0·47 per cent K_2O), and further that these are at least in part soluble in water charged with carbonic acid, an estimate of the solubility of various constituents of different *kankar* samples in CO_2 water was undertaken. Three samples of *kankar* and one of ferro-manganiferous concretions were placed in gooch crucibles and leached with CO_2 water at 35°C. (0·12 per cent by weight) till almost free of calcium. The results of analysis are given in Table VIII.

TABLE VIII

Composition of CO_2 water leachate of kankar *sample*

—	Parts per million.			Fe.Mn. concretions
	Mature	Mature	Mature dolomitic	
Fe_2O_3	2·88	0·60	0·36	0·70
P_2O_5	0·20	0·06	0·02	0·14
CaO	495·6	264·5	35·0	28·9
MgO	5·0	1·5	30·0	2·5

The results show that some of the samples give appreciable quantities of nutrients and are thus of use to crop. It is interesting to note that the Fe.Mn.concretions yield comparatively small amount of P_2O_5 in view of the fact that it has 0·84 per cent P_2O_5.

F. *General.* *Kankar* has a *p*H of 8·2 to 9·0 and is non-magnetic. It does not contain any appreciable organic matter, as evidenced by action of hydrogen peroxide. Even the ferro-manganiferrous concretions are non-magnetic and devoid of organic matter. Their *p*H is 7·0 to 7·2.

DISCUSSION

1. *Nature of* kankar. The use of word '*kankar*' or '*kunkur*' to designate concretions or nodules of lime carbonate found in India is well recognized [Sigmond, 1938; Hilgard, 1930]. In practice, however, this term is applied for various kinds of formations in the soils, e.g. lime nodules, lime concretions, lime stone slabs locally called *bichhwa, kankar, ror* and *bhata* respectively.

These formations may be said to be the different types of *kankar*. A photo of these together with other types of *kankar* studied is given in Plate XXII, fig. 2 and Plate XXIII, fig. 2.

On the basis of physical and chemical characters for these samples, reported earlier, and microphotographs (Plate XXIII, fig. 1), one may say that *kankar* is essentially a mixture of 50-75 per cent of lime carbonate (or at times lime and magnesium carbonate) with 13-57 per cent of soil in which it is formed. These together with varying amount of free sesquioxides, P_2O_5, Mn_2O_3, etc., form a concretionary or nodular body. It is definitely of the nature of a secondary formation as distinct from impure lime stone. In consistency it is soft (Moh's hardness No. 1-3) in the initial stages of formation and becomes hard (hardness No. 7) with maturity.

Gillam [1937], in his description of the lime concretions of Moody and Crofton series, has mentioned that they are annular in structure. The micro-photographs of *kankar* samples (Plate XXIII, fig. 1), however, do not exhibit this structure. These photos further show that calcium carbonate (calcite) has deposited round quartz, clay and other minerals in rather an irregular manner and has

cemented the whole mass. This structure suggests the deposition of calcium carbonate in pores, cavities, channels, etc., through which water movement in the liquid state took place.

2. *Relationship of* kankar *type and percentage of carbonates of mother soils.* Looking up the characters of mother soils for all *bhata* (slab type) and *bichhwa* (scorpion) types of *kankar* samples from Rohtak district, they are found to contain the following quantities of carbonates :

Kankar type	Average percentage of carbonates	No. of samples
Bichhwa	6·40	20
Bhata	23·85	4

The above data point out that slab type of *kankar* develops in soils with very high percentage of $CaCO_3$—about 24. This may be due to the fact that the initially large percentage of carbonates, supplemented by leached carbonates received in the non-capillary pores, is enough to cement the whole mass and transform it into *kankar*. It may be stated that *kankar* contains about 50-60 per cent of carbonates. However, several other factors may be involved. Another significant difference between the mother soils of two types is that those giving slab type are richer in magnesium carbonate.

3. *Porosity of* kankar *as an index of the stage of soil profile.* In the initial stages of *kankar* formation, calcium carbonate deposited is more or less loose. It gets compact either by inclusion of fresh $CaCO_3$, sesquioxides, etc., with the progress of the process, or only by pressure or by both. It follows, therefore, that the percentage of pore space in *kankar* should bear a relationship to the stage of soil profile. It is seen from Table I that the percentage of pore space in *kankar* goes on decreasing till the soil profile becomes semi-mature, after which there is no change.

As $CaCO_3$ in the horizons overlying *kankar* becomes lower by progressive leaching, the stage of a soil profile is related with the amount and distribution of $CaCO_3$ in the profile. The young and immature profiles have lot of carbonates in the horizons overlying *kankar*, whereas the more mature ones do not have any in the horizons overlying *kankar*. Percentage of pore space in *kankar*, therefore, should bear a relationship with percentage of carbonates of the overlying horizons. When the two sets of data are studied it is seen that in general pore space in *kankar* decreases as the percentage of $CaCO_3$ of the horizons overlying *kankar* becomes lower. Thus it may be said that porosity of *kankar* is a fairly good index of the stage of soil profile.

4. *Depth of* kankar *horizon.* Depth of *kankar* horizon is found to vary widely even at places small distances apart. Wyssotski [1899] and Hilgard [1930] believe this depth indicates the depth of penetration by rain water. Shantz [1923] thought it to be the region of desiccation of moisture by plant roots. Gillam [1937] has discussed the whole problem and maintains that the percentage of $CaCO_3$ in the profile is a major factor. A profile with a high content of calcium carbonate will develop the horizon higher than one with a relatively low percentage of $CaCO_3$ due to the ability of the former to saturate the leaching water with $CaCO_3$ at a much higher level. The various factors controlling the depth of the horizon may be grouped as under :

1. Depth of infiltration of water.
2. Percentage of $CaCO_3$ of the profile.
3. Depth of the layers desiccated.

In the profiles examined there is evidence of all these factors affecting the depth of *kankar* horizon. The available data for a few profiles are depicted in columns drawn for each profile (Fig. 1). No single factor explains all the results. The problem, however, is a very complicated one, and more data are required to make any definite observation.

5. *Factors affecting chemical composition of* kankar *under the same climate.* From a consideration of the process of *kankar* formation, it may be concluded that as 13-57 per cent of *kankar* is mother soil, its (mother soil's) composition should affect *kankar* composition. A reference to results of the analysis of mother soils and respective *kankar* samples shows that a relationship does exist.

As examples, it is seen that the dolomitic soils give rise to samples rich in magnesia. Further, the colour of the *kankar* sample is similarly influenced by that of the mother soil.

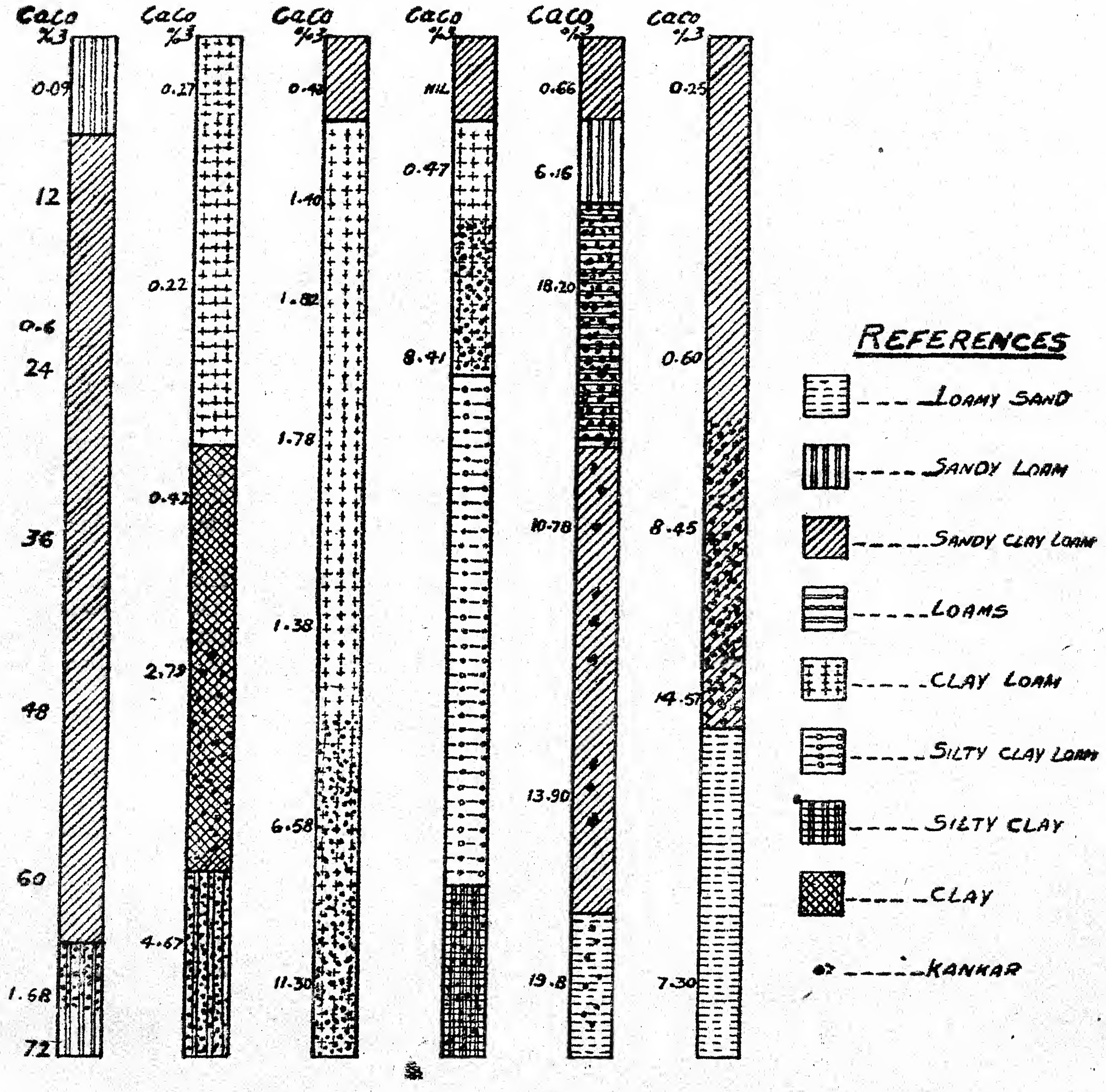

FIG. 1. Depth of *Kankar* horizon and soil characters

That *kankar* contains much larger quantities of carbonates than the mother soil needs no mention. This large percentage of carbonates in *kankar* affects the gross percentage figures of other constituents, and a comparison of other constituents with those of mother soil containing comparatively much less carbonates is not sound. To compare the composition of the mother soil and *kankar* regardless of carbonates, these should be expressed as percentage on carbonate free material. The results of such a comparison are set forth in Table IX.

TABLE IX

A comparison of the composition of mother soils and respective kankar *samples*

Percentage on carbonate free material

Serial No.	Profile	Stage	Moisture	Insoluble residue	Fe_2O_3	Al_2O_3	P_2O_5	Mn_2O_3	CaO	MgO	K_2O	Na_2O	
1	Lyallpur .	Young .	1·55	77·74	6·59	7·15	0·474	1·100	12·06	2·61	1·35	0·75	*Kankar*
			1·55	81·34	4·92	5·90	0·154	0·038	0·98	1·57	..	0·64	Mother soil
2	Rohtak .	Immature .	0·54	79·84	5·30	10·14	0·152	0·091	*Nil*	..	0·54	0·93	*Kankar*
			1·55	80·16	4·39	6·82	0·147	0·060	..	3·60	0·40	0·20	Mother soil
3	Rohtak 1B (v)	,, .	1·76	81·68	6·59	8·68	0·100	0·459	..	2·73	0·61	0·50	*Kankar*
			1·94	81·93	2·93	8·61	0·103	0·039	..	1·99	0·57	0·41	Mother soil
4	Rohtak 1B (iii)	Semi-mature	1·08	79·92	7·55	9·06	0·188	0·071	*Nil*	N.D.	0·47	..	*Kankar*
			1·90	77·66	6·05	6·02	0·100	..	..	2·02	0·72	0·39	Mother soil
5	Rohtak 1B (ii)	,, .	..	62·25	6·55	15·07	0·150	0·196	4·30	5·33	..	..	*Kankar*
			..	69·23	4·71	14·96	..	..	0·89	1·43	..	..	Mother soil
6	Rohtak 1B .	,, .	0·67	79·78	4·08	4·57	0·150	0·196	0·62	2·82	0·77	0·22	*Kankar*
			0·755	89·20	3·06	4·26	0·094	0·020	0·87	1·31	0·16	0·34	Mother soil
7	Rohtak 1A (i)	Mature .	1·06	74·87	6·00	5·93	0·150	0·217	..	4·43	0·44	N.D.	*Kankar*
			0·80	85·88	3·44	5·30	0·090	..	..	0·68	1·01	0·40	Mother soil
8	Rohtak 1A (ii)	,, . .	*Nil*	54·87	6·93	4·59	0·074	0·080	8·21	..	0·79	..	*Kankar*
			1·55	80·84	4·18	8·19	0·034	..	..	0·90	0·72	0·28	Mother soil
9	Rohtak Slab Type	Immature .	1·18	82·13	5·02	8·08	0·151	..	..	2·28	0·66	0·12	*Kankar*
			..	85·96	3·61	5·24	0·105	0·031	..	2·16	0·39	0·41	Mother so il

Comparing the results of insoluble residue from samples of various stages, we find a small differ ence (77·7 and 81·3 per cent for *kankar* and mother soil respectively) in the case of young profile (Lyallpur). The samples from immature profiles have practically the same insoluble residue as the mother soil. A progressive lowering in samples from more mature profiles is noted. The two samples from mature profiles have 74·7 and 54·9 per cent insoluble residue as compared to 85·9 and 80·8 per cent respectively of their mother soils. The two slab type samples have practically the same insoluble residue as their mother soils.

All the *kankar* samples are richer in iron than the respective mother soils, the difference varying from sample to sample. The excess is present very probably as free Fe_2O_3 in the form of limonite. The *kankar* samples, in general, contain as much alumina as the mother soil. The slab type sample is, however, found to contain 8·08 as compared to 5·2 in the mother soil. Percentage of P_2O_5 in Lyallpur *kankar* sample (0·474 per cent) is considerably higher than for the mother soil (0·154 per cent). The immature samples contain as much phosphorus as the mother soil, whereas the semi-mature and mature ones higher quantities.

Some of the *kankar* samples are much richer in manganese, samples from mature and semi-mature profiles containing higher quantities. Figures for potash and soda do not show any consistent difference, and the *kankar* samples, in general, contain as much of these constituents as the mother soil. Nothing can be said with certainly about lime and magnesia, as in allowing for a large percentage of carbonates and its distribution as between lime and magnesia in dolomitic samples, a large error creeps in.

In view of the above, it may be said that when *kankar* and mother soil analysis are expressed as percentage on carbonate free material, the two more or less agree in alumina, potash and soda. As regards other constituents, the nature of soil conditions determines their amount, e.g. iron, phosphate and manganese in *kankar* tend to be higher in *kankar* when compared to that in mother soils more particularly for mature profiles. In the case of mature soil profiles, these constituents may some time segregate as ferruginous concretions of the composition given in Table II. Insoluble residue in the case of mature samples is lower than that of the mother soils which cannot be readily explained. It may possibly be due to the preferential mixing of finer particles of mother soil with $CaCO_3$, and as these are less siliceous, the resulting product is also less siliceous.

The formation of spherical or rounded concretions in heavy soils as compared to large irregular and angular nodules in light soils (described previously) is probably due to the difference in size of soil crumbs, pore size, etc. The process of deposition of carbonates in non-capillary pores remains more localized in heavy soils, but spreads round widely in light soils.

To sum up, the composition of *kankar* samples from the Indo-Gangetic alluvium has been found to depend on the following factors :

(i) Texture of the mother soil. Heavy textured soils give rise to higher carbonates and correspondingly less of siliceous matter.

(ii) The composition of mother soil. Its effect may be judged from the fact that when *kankar* composition is expressed as percentage on carbonate-free basis, the figures agree fairly closely with percentage composition of the mother soil on the same basis. The main difference lies in iron, manganese, phosphorous and to less extent in silica. The former exist as free oxides. If due allowance is made for them, a good idea of the composition of mother soil may be had from *kankar* analysis.

To ascertain whether the above constituents exist as free sesquioxides or not, five *kankar* samples and one ferruginous concretions sample were analysed for their free sesquioxides and silica. Due to large percentage of calcium carbonate in the *kankar* samples, the sesquioxides, precipitated as sulphides in Drosdoff and Truog's method, could not be estimated. The data for the ferruginous concretions from a degraded profile from Rohtak are given below :

Experimental			Calculated		
Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3	SiO_2
12·06	0·19	1·00	12·65	2·55	..

It may be said, therefore, that at least in the ferruginous concretions, the balance of Fe_2O_3, as calculated from analysis of concretions and mother soil on the basis of SiO_2, exists as free sesquoxides. And probably the same is true about *kankar* as well.

To elucidate the latter point further, sections of four typical samples of *kankar* were prepared, examined and micro-photographs of two of them taken by the Director, Geological Survey of India, Calcutta, on request. The relevant extract from his report is reproduced below and the micro-photographs are illustrated in Plate XXIII, fig. 1.

(I) 1K. Kankar (mature—Rohtak). The mineral constituents are quartz up to 0·15 mm. and about 30 per cent of volume of rock ; calcite ; muscovite ; biotite with calcite growing as wedges between the cleavage lamellae ; clay matrix ; opaque oxides ; and hornblende.

(II) 7K. Kankar (immature—Rohtak). The mineral constituents are quartz up to 0·17 mm. averaging 0·08, and about 15 per cent of the volume of the rock ; calcite ; muscovite ; oxidized biotite ; much brown semi-opaque oxides probably limonite dendritic opaque oxide, possibly pyrolusite and clay matrix.

(III) 15K. Kankar (semi-mature dolomitic—Rohtak). The mineral constituents are quartz up to 0·15 mm. and about 20 per cent of the volume of the rock ; calcite ; muscovite ; hornblende ; clay matrix ; opaque oxides ; probably limonite.

(IV) 20K. (mature—Jullundur). The mineral constituents are quartz averaging 0·05 mm., and about 10 per cent of the volume of the rock; calcite; muscovite; biotite; scattered opaque oxides; probably limonite and clay matrix.

'(1) It is seen that free quartz occurs in all the slides. Volumetric estimates are by eye and only approximate.

'(2) No. 7K is exceptional in the presence of much semi-opaque brown oxide—probably limonite and of dendritic opaque oxide—possibly pyrolusite.

'(3) A certain amount of limonite material has developed in all the specimens from the oxidation of biotite.

'(4) It is not possible to determine the nature of the oxides.'

It may be seen that as postulated above *kankar* does contain varying degrees of free oxides of iron and manganese. It is, however, unfortunate that even this method fails to estimate the quantity of free oxides, and thus no direct estimation of the calculated amount has been possible.

The micro-photographs also indicate the probable mode of formation which consists in the deposition of calcite, etc. in between clay matrix and quartz grains.

6. *Effect of climate and soil type on* kankar *composition.* The varied nature of mother soils in different climates and soil types is well known, and since it enters into the composition of *kankar* to varying degrees, a variation of *kankar* composition with these changes may be expected. However, if we compare the mother soil and *kankar* composition on carbonate free material for samples from varied climates and soil types, more fundamental differences are noted. The results of such a comparison are set forth in Table X.

TABLE X

A comparison of the composition of the mother soils and respective Kankar *samples from different climates and soil types*

Serial No.	Locality	Soil types	Meyer's N/S quotient	Moisture	Insoluble residue	Fe_2O_3	Al_2O_3	P_2O_5	Mn_2O_3	CaO	MgO	K_2O	Na_2O	SO_3
				(Percentage on carbonate free-basis.)										
1	Bahrein	Desert	13·3	0·72 1·31	84·13 90·54	1·24 1·23	1·40 1·90	0·124 0·100	..	3·05 1·11	3·11 2·0	0·12 10·22	0·51 0·36	0·91 0·60
2	Lyallpur	Alluvium	40·0	..	77·74 81·34	6·39 4·92	7·15 5·96	0·470 0·154	0·100 0·038	2·06 ..	2·61 5·62	1·35	0·75 0·64	*nil*
3	Ferozepur	,,		0·67 0·75	79·78 89·20	4·08 2·06	4·57 4·26	0·150 0·094	 0·02	0·62 0·87	2·82 1·31	0·77 0·16	0·22 0·34	*nil*
4	Rohtak immature	,,	46·9	1·76 1·94	81·68 81·93	6·59 2·93	8·68 8·61	0·100 0·103	0·06 0·05	*nil* ,,	2·73 1·99	0·61 0·57	0·50 0·41	
5	Rohtak mature	Gypseous	46·9	0·64 1·65	67·11 80·40	6·38 4·71	8·76 6·11	0·253 0·094	0·40 0·04	4·16 1·61	3·80 1·48	0·57 0·72	0·42 0·36	Trace 1·18
6	Deoria ,,	Limy alluvium Limy ferruginous molten soil	192·4	1·30 5·23 2·83	69·58 58·64 83·42	5·07 14·11 3·66	6·71 10·64 5·19	0·095 0·124 0·062	0·59 .. 0·62	0·48 0·32 1·22	4·83 2·66 2·25	.. 0·64 0·09	0·41 0·53 0·28	*nil*
7	Bijapur	Regur	57·9	8·95* 9·24	18·73 63·43	42·38 9·63	15·84 15·39	0·212 0·085	.. ..	2·12 0·61	0·77 0·34	1·01 0·61	N.D. ,,	N.D. ,,
8	Indore	Limy White Limy Black molten soil	96·4	.. 6·63 2·89	53·69 49·89 69·24	6·85 10·31 5·50	13·65 13·57 12·82	0·112 0·174 0·105	0·37 2·13 0·24	2·07 4·58 0·20	3·02 4·26 1·63	1·42 1·29 1·17	1·22 0·81 0·62	
9	Mt. Edgecombe	Coastal primary	225·4	3·02 4·24	58·15 68·56	10·47 7·20	4·08 10·65	0·126 0·060	0·19 0·11	4·57 0·43	3·23 0·82	1·21 0·98	0·46 0·47	Trace ,,
10	Matanzas	Lateritic	250·0	11·67 11·81	16·06 26·63	47·74 31·20	18·66 28·42	0·21 0·17	0·87 0·32	1·60 0·07	0·47 0·42	0·27 0·34	1·70 1·68	N.D. ,,

The lower line reports results of mother soil analysis.
* *Loss on ignition figures.*

It is seen that concretions and mother soil from desert differ only in carbonate content. The Ferozepur and Lyallpur samples from arid climate (Q-40) have practically the same insoluble residue (77·7 and 79·8 per cent) as the mother soil (81·3 and 89·2 per cent), and slightly more of iron, phosphate, manganese. Other constituents do not show any difference.

In contrast with this, the sample from Deoria (Q-192) although derived from a soil profile containing a lot of carbonates in the surface and alkaline reaction, contains much less insoluble residue (69·6 per cent) than the mother soil (83·4 per cent). Iron oxide (5·1 per cent), manganese (0·59 per cent) and phosphorus (0·095 per cent) in *kankar*, too, are greater than what the mother soil has. Further the upper horizon contains 1·69 per cent limy ferruginous concretions which have much more of iron (14·1 per cent), P_2O_5 (0·124 per cent), Mn_2O_3 (6·9 per cent) and even alumina. The *kankar* samples from a mature profile from a more arid climate show similar composition. Further it is seen that *kankar* from even a slightly gypseous soil profile does not contain any gypsum.

The limy ferruginous sample from Bijapur is much less siliceous (18·7 per cent), has a high iron (42·4 per cent) and phosphate (0·21 per cent) content than the mother soil, which has 63·4, 9·6 and 0·085 per cent of these constituents respectively. Analysis of the limy samples is not available but from the description given by Kanitkar *et al.* [1935], it appears to consists entirely of $CaCO_3$ and much less of iron and silica.

Results of comparison for the white and black *kankar* samples from Indore with mother soil also show both the *kankar* samples to be less siliceous (53·9 and 49·9 per cent insoluble residue). Unlike samples of *kankar* from Bijapur or Deoria, the black sample does not contain very high percentage of iron. As pointed already, the white and black *kankar* differ in the former being more siliceous, containing more carbonates and alumina than the black one. Both the white and black *kankar* samples contain more of iron than the mother soil.

The Mt. Edgecombe sample has several features in common with that of the Rohtak samples, e.g. the *kankar* (lime concretion) and mother soil when expressed as percentage on carbonate free basis agree fairly closely except for slightly less silica, higher iron, phosphate, and manganese, but unlike the Rohtak samples the concretions contain much less alumina than the mother soil.

The perdigon samples from Matanzas (Cuba) have been included in the list to serve as an example of the Pedalfer group of soils. The perdigon is less siliceous, has more iron and less alumina than even the mother soil.

If we strike a balance sheet for composition of these concretions from the mother soil analysis on the basis of percentage of mother soil contained in them, the above conclusions are found to hold good.

It is interesting to see that the results arrived at by comparison on carbonate-free basis are substantiated by the results of comparison of SiO_2 basis.

When we review the above in the light of conditions of soil formation, the following remarks may be made:

(*a*) The accumulation of gypsum besides carbonates in Bahrein samples is due to the very low rainfall of the desert area.

(*b*) The accumulation of iron, phosphate, manganese and, of course, of carbonates, is due to decrease of aridity in Punjab samples. As the soil profile becomes mature, *kankar* and mother soil analysis on carbonate-free basis differ, the former containing less silica, more iron, phosphorus, manganese, etc. Sometimes these constituents may segregate as ferruginous concretions or rarely even as limy ferruginous concretions. Under conditions of higher rainfall, the above concretions are met with more abundantly and even in immature soils.

The release of these constituents and their deposition in *kankar* is due to either of the following:

(i) Leaching with CO_2 water in the absence of carbonates and neutral to faintly acid reaction, e.g. degraded profile (IB iii) and mature profile (IA ii).

(ii) Lack of aeration due to excessive moisture in wet season and a possible effect of the decomposition products of organic matter even in the presence of carbonates, e.g. in Deoria, Lyallpur samples, etc.

(iii) The activity of iron bacteria: It has not been possible to estimate their role.

(*c*) The definite accumulation of iron in concretions from regur (Bijapur) is not understood in view of the fact that even the surface soil contains as much as 18 per cent calcium carbonate, and further its distribution in the profile does not indicate any evidence of

leaching. Erosion in this tract is very severe as has been described by Kanitkar and co-workers [1940]. It may be that this is a truncated profile in which the leached horizon (A) has been removed. The decided decrease of silica also cannot easily be explained and may indicate the lateritic tendency in the original profile. More work in this direction is needed.

(*d*) The accumulation of iron and alumina and phosphorus, etc. in Indore *kankar* samples is not well understood. The data kindly supplied by Dr A. Sreenivasan indicated that the soils have been subjected to alkaline hydrolysis. The presence of concretions in the surface and their decrease in quantity with depth suggests that like the Bijapur soil they may also be truncated, and the exposed 'B' horizon has been further subjected to leaching. The small accumulation of alumina is, of course, due to alkaline hydrolysis.

(*e*) A loss of silica in concretions from Mt. Edgecombe may also be explained as a probable consequence of higher rainfall and high temperature, high *p*H (8·8). As regards loss of alumina in contrast to profiles from Rohtak, a reference to the analysis of soil profiles and the published account of Beater [1941] show that the nature of alumino silicates is probably responsible for the difference. Beater mentions that percentage figures of iron and alumina for HCl extract and fusion analysis of these profiles do not differ. In contrast to this a very great difference of alumina percentage for HCl extract and fusion analysis results has been found for profiles from Indo-Gangetic alluvium.

(*f*) The lateritic type of soil forming processes in Cuba accounts for the decrease of carbonates and silica, and a great increase of iron.

SUMMARY

1. *Kankar*, a hard lime concretion or nodule of the nature of a secondary formation, is met with widely in Indo-Gangetic alluvium and Black Cotton tracts. It presents a variety of shape, size, colour, etc. Results of a study of the relationship between its composition and the nature of its soil profile are presented.

2. *Kankar* consists of 50-70 per cent of $CaCO_3$, and 25-45 per cent of mother soil and a small percentage of free iron oxide, manganese oxide and phosphate, the exact amount depending on the condition of soil profile. In general it consists of 45·3-73 per cent $CaCO_3$, 1·84-4·08 per cent Fe_2O_3, 1·22-5·9 per cent Al_2O_3-P_2O_5, 0·03-0·08 per cent P_2O_5, trace to 0·23 per cent Mn_2O_3, 1·3-10·5 per cent MgO, 0·05-0·47 per cent K_2O, 0·11-0·05 per cent Na_2O.

In certain cases limy ferruginous concretions and ferruginous concretions are formed but the circumstances leading to their formation are not understood. There is a progressive decrease of pore space and increase of hardness of *kankar* with increase in maturity of soil profile.

3. An examination of section of *kankar* samples of different maturity and of their microphotographs confirms the above conclusions regarding the presence of varying amounts of free sesquioxides and Mn_2O_3 in *kankar*. Comparison on SiO_2 basis and carbonate-free basis with the mother soil also confirm the above view point.

4. Texture of the mother soil affects the size, shape and carbonate content of *kankar*. Samples from heavy textured mother soils are smaller in size, semispherical, with no holes penetrating through them and have a relatively high carbonate content (60-70 per cent). Those from light textured mother soils are larger, irregular, angular and with holes penetrating through them and have less of carbonates (50-60 per cent).

5. Analysis of samples of *kankar* and lime concretions from different climates and soil types show fundamental differences. With decrease in aridity there is an increase of iron, phosphorus and manganese. The data point out a relationship of soil conditions with analysis of concretions.

6. Comparison of the composition of these concretions and that of respective mother soils on the basis of carbonate free material brings out the effect of climate and soil type. The changes in compositions are discussed with reference to soil conditions.

7. When the constituents derived from mother soil are accounted for on the basis of silica content, the balance of constituents for the various samples suggests the presence of small amounts of free

iron oxide, manganese oxide, and phosphate. The results for other samples from different soil types confirm the conclusions arrived at by comparison on carbonate-free basis. In view of the above, a study of the composition of secondary formations as an aid in soil genesis is suggested.

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REPUTED ABORTIFACIENT PLANTS OF INDIA*†

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ABORTIFACIENTS are drugs or agents that cause abortion, i.e. the expulsion of the fœtus prematurely, particularly at any time before it is viable, or capable of sustaining life. The gestation period, i.e. the carrying period of the young in the womb from conception to delivery, varies in different animals, and so far as human beings are concerned, the term abortion usually implies the expulsion of the fœtus during the first six months of pregnancy. Expulsion of the fœtus after the

* A considerable amount of work in connection with this paper was done by the late Mr N. C. Goswami, Botanical Assistant in this Inquiry

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sixth month when it is viable, but before the normal period of nine months, is generally termed premature delivery or labour. The popular term miscarriage is usually applied to an abortion before the sixth month, sometimes only in case of abortion between fourth to sixth month, occasionally before the sixth week of gestation, and rarely even to a premature labour. In law, however, the term abortion usually implies criminality in producing miscarriage for an improper purpose at any time of gestation short of full term, and means premeditated or intentional abortion produced by artificial means, solely for the purpose of preventing the birth of a living child ; it is designated as criminal abortion.

For the purpose of this paper abortion may be divided into three categories, viz. (*a*) natural abortion, (*b*) artificial abortion, and (*c*) criminal abortion or fœticide.

(A) Natural abortion

The causes responsible for naturally occurring cases of abortion are various. They may be due to the poor condition of the mother's blood or poisons circulating in the same, mechanical disturbances of the circulation, diseases of the genito-urinary organs, over-indulgence in sexual intercourse by the mother during pregancy, nervous causes, syphilis, streptococcal infections, etc. Abortion may also naturally be due to the disease of the membranes of the ovum or fœtus or diseases of the embryo itself.

(B) Artificial abortion

In certain cases the law permits the induction of premature labour and abortion if competent medical opinion decides that the life of the mother is in danger. This, however, is not resorted to unless all other means for preserving the life of the mother, and if possible that of the child also, have failed.

(C) Criminal abortion or fœticide

Criminal abortion is, for a variety of reasons, induced with the sole object of unlawfully destroying the impregnated ovum or the fœtus, and the law holds the attempt to do so equally guilty with the actual accomplishment. It has no moral, religious, social or legal sanction. Nevertheless, criminal abortion is undoubtedly prevalent in India as in other countries, although only relatively a small proportion of the cases are brought to light. Although no reliable statistics are available, it could perhaps be said with certainty that, on account of increase in population and the consequent ever-increasing struggle for existence together with a continued demand for higher standard of living, it is the married couples who are the most frequent perpetrators of this nefarious crime. Many a parent can ill-afford the educational and other expenses of a large number of children and simultaneously maintain the social position to which they belong. They feel the inconvenience of supporting a large family, and, without any compunction, conspire to get rid of their unborn baby. On the other hand, unmarried girls and widows, to get rid of the fruits of illicit intercourse and to hide the shame of their illegitimate pregnancy, also form a considerable percentage of these criminals.

Owing to the advent of various kinds of the so-called contraceptives it could be safely deduced that the necessity and frequency of resorting to abortion is on the decrease. These appliances for the prevention of fertilization of the ovum are, however, beyond the means of a vast majority of Indians, whose economic condition is very low. On the other hand, the use of the so-called infallible contraceptives by the married as well as the young, unmarried, inexperienced girls has not infrequently led to undesired pregnancy.

As soon as suspicion is aroused with regard to the condition of the female—after the omission of one menstrual period—the economic responsibilities in the case of married couples, the sense of shame and social abhorrence in the case of widows and unmarried girls, and loss of business in the case of prostitutes, become urgent considerations. The urge of getting rid of the 'unwanted arrival' begins to get strong and the advice of confidential friends is sought. Usually some drugs are recommended which are tried at first. At many drug stores, medicines supposed to produce abortion are on sale, and many nostrums advertised to correct female irregularities are made, bought and used to procure abortion. Generally, however, they prove ineffectual ; and then active steps are taken to enlist the services of professional abortionists. These abortionists vary greatly in education

and technical skill. Some are well qualified for the purpose, while others, such as most of the *dais* or country midwives who mainly use drugs of vegetable origin or rash mechanical means, are quite ignorant of aseptic precautions and of the rudiments of anatomy. The patient sometimes learns from an abortionist a method of direct interference with the uterus, and, if this is successfull, she proceeds to apply it herself when another occasion arises. Often the woman does not realize the condition of her pregnancy till between the fourth and fifth months, when owing to the symptoms of quickening, she can no longer remain ignorant. At whatever time of gestation abortion is resorted to, it is attended with grave risk to the life of the unfortunate mother, unless it is performed by highly qualified gynæcologists. Since the services of expert gynæcologists are not easily available for the purpose of criminal abortion, the patient usually falls into the hands of quacks and often dies.

Criminal abortion endangers the mother's life by causing profuse hæmorrhage as a result of retention of the placenta or some other product of conception, or by septic inflammatory processes. In the case of abortion, which is procured through the agency of various instruments, perforation into the peritoneal cavity and septicæmia are the usual causes of death. It is interesting to note that more women die during attempt to procure criminal abortion than from childbirth and its complications. Peritonitis is the most common cause of death and is responsible for more than half the fatal cases. General septic infection kills about one-fourth. The remainder die from embolism, pneumonia or some other incidental infection [Davis, 1923]. Serious illness after criminal abortion is very common.

It is popularly believed that the earlier the period at which abortion is procured, the lesser is the danger to the life of the mother. This is not true. During the early gestation period the contractile powers of the muscles of the uterine walls are limited and hence the chances of hæmorrhage great owing to the non-occlusion of the bleeding vessels. At or near the completion of the term they are able to contract firmly and so occlude the bleeding vessels. Furthermore, if the uterus has not contracted thoroughly, the open sinuses are liable to absorb septic matter, so that septic infection is of much more frequent occurrence if the abortion occurs during the earlier periods of pregnancy than after delivery at the full term.

Methods of procuring abortion

The methods of procuring abortion are varied. Among these may be mentioned severe exercise, violent shaking of the body, tight lacing of the abdomen, and even trampling or kicking of the abdomen or other severe violent means. Mechanical means are also applied with a view to disturb the relation between the uterus and its contents, and are usually quite effective although usually accompanied with grave danger to the mother's life. For this purpose various kinds of instruments, such as wires, bones, twigs, etc. are used with the object of perforating the membrane surrounding the fœtus.

In India, quite a large number of *dais*, who practise the unlawful trade, introduce into the vagina or the *os* of the uterus sticks from six to eight inches long, which are commonly known as 'abortion sticks'. One end of these sticks is wrapped round with a piece of rag or cotton wool soaked with the juice of such plants as *madar* [*Calotropis procera* (Linn.) Dryand. and *C. gigantea* (Linn.) Dryand.], marking nut (*Semecarpus anacardium* Linn. *f.*), jequirity (*Abrus precatorus* Linn.), etc.; other ingredients of medication used for abortion sticks are arsenious oxide, orpiment and red lead. Some of the plants, the irritant twigs of which are similarly used, are *Plumbago indica* Linn. (*P. rosea* Linn.), *P. zeylanica* Linn., euphorbiaceous plants, and less frequently *Nerium indicum* Mill. (*N. odorum* Soland). These twigs are frequently smeared with asafœtida prior to introduction. The oral administration of reputed abortifacient drugs is, however, more frequently resorted to than any other method for procuring abortion.

Oral administration of abortifacient plants

It may be stated at the outset that administration of the so-called abortifacient drugs seldom answers the purpose for which they are used. When the desired object is attained, it is generally

from the use of a poisonous quantity, so that when the abortion is procured it is often followed by dangerous poisoning or death of the mother; not infrequently the mother dies without the production of abortion at all. It may be noted that all poisons, when taken in sufficiently large doses, may act as abortifacients, but such doses are generally attended with grave risks to the life of the mother.

Some of the plants used as abortifacients are supposed to produce uterine contractions which expel the contents of the gravid uterus: these are called ecbolics. Others, when used in the non-gravid condition, are supposed to promote menstrual flow or to re-establish it after its arrest from causes other than pregnancy: these are called emmenagogues. Still others have poisonous effects on the system generally.

The drug that enjoys the greatest reputation as an ecbolic is ergot, which is the sclerotium of the fungus *Claviceps purpurea* Tulasne, developed in the ovary of rye, *Secale cereale* Linn. It is a well-known medicine for exciting uterine contractions. It may be noted that while ergot is certainly capable of producing contractions of the uterus during the later stages of pregnancy, it is doubtful whether it can initiate uterine contractions in women during the early stages, or produce them with sufficient force so as to cause the expulsion of the fœtus. Some observers are of the opinion that ergot acts upon the uterus only when natural contractions of this organ have already begun; but, since uterine contractions normally occur during pregnancy it is conceivable that ergot may be able to augment the force of these contractions, although in the early months of pregnancy it may not be able to increase them sufficiently to procure abortion. Quinine from species of *Cinchona* is another drug which stimulates the contractions of the uterus when given in large doses; abortions have occasionally occurred after its use in malaria, while in other cases labour pains may be induced. Therapeutic doses, however, do not in most cases suffice to excite persisting activity in the quiescent gravid uterus, and are, therefore, not reliable for inducing premature labour, but if weak contractions are present, they are intensified. Like ergot it is conceivable that quinine may be able to augment the normal contractions of the uterus during pregnancy, but it may not be able to increase them sufficiently to procure abortion.

The emmenagogues, which often increase the menstrual flow in the non-gravid uterus, are very largely employed to induce abortion. They include all well-known drastic purgatives, such as alœs (*Aloe barbadensis* Mill.), and irritant volatile oils, such as pennyroyal (*Mentha pulegium* Linn.), savin (*Juniperus sabina* Linn.), tansy (*Tanacetum vulgare* Linn.). These are all intestinal irritants, and produce violent gastroenteritis (nausea, vomiting and diarrhœa). If the poison acts only when dissolved and is insoluble in the stomach, as is croton oil (from *Croton tiglium* Linn.), the nausea and vomiting may not be present, but only the diarrhœa. The hyperæmia produced is not confined to the intestines, but all the neighbouring abdominal organs partake of the congestion, although they do not come in direct contact with the irritant. It must be remembered that these emmenagogues produce their ecbolic effect only secondarily to the gastro-enteritis; the latter may be so violent as to be fatal without accomplishing the desired result. None of the intestinal irritants (drastic purgatives and irritant volatile oils) are suitable for procuring abortion and should never be employed as ecbolics. The volatile oils may, however, be useful as emmenagogues.

Besides the ecbolics and emmenagogues, some general poisons, such as Indian oleander (*Nerium indicum* Mill., syn. *N. odorum* Soland.), are also administered in India for procuring abortion. There does not appear to be any basis for their use, except that by acting as general poisons they may occasionally achieve abortion. There is always a grave risk to the life of the mother when these plants are employed.

A perusal of the above will show that there is no reliable plant or its product for procuring abortion, without endangering the mother's life. Despite this, the fact remains that ignorant persons do employ something or the other to achieve the object. Chopra and Badhwar [1940] have published a comprehensive list of Indian plants poisonous to man, livestock, insects and fishes. Their studies have revealed that a large number of plants are used in India for the purpose of procuring criminal abortion. In the present paper we deal with Indian plants which are applied locally on account of their irritant juices or are administered orally to procure abortion. A list of such plants, their important English and vernacular names, distribution, chemical constituents, properties and methods of use are discussed in the Appendix. Only plants indigenous to or cultivated in India are dealt

with. Plants or their products, like pennyroyal, savin, tansy, etc., although commonly used as emmenagogues or abortifacients in Western medicine and available at druggists' shops in India are excluded, since they do not grow in India. Further, such plants as croton, a drastic purgative found in India, will act like other drastic purgatives mentioned in the list, are also excluded, because they are not known to be used as abortifacients in this country.

The authors take the opportunity of expressing their grateful thanks to Col. Sir R. N. Chopra, C.I.E., for the help and guidance he has given in the preparation of this paper.

Appendix

Name of plant	Distribution	Constituents	Remarks
1. *Abrus precatorius* Linn. *English* : Crab's Eyes—the seeds, Indian Liquorice—the roots, Jequirity, Rosary Pea — the seed. *Vernacular* : *Gunchi, Gunja, Rattak, Ratti.*	Throughout the greater part of India, ascending the outer Himalayas to an altitude of 3,500 ft. ; sometimes planted in gardens.	Seeds contain the toxalbumin 'abrin' [Osborne, 1924], a crystalline nitrogenous compound abrine and an amorphous glucosidic substance abraline with a mild bitter taste [Ghatak and Kaul, 1932 ; Ghatak, 1934]. Leaves said to contain abrin and the leaves and roots glycyrrhizin [Wehmer, 1929-35].	Seeds ground into a paste and the mass made into sharp pointed needles used to procure criminal abortion : for this purpose the juice of the plant also used as a local application. Powdered seeds when taken internally by women said to disturb the uterine functions and to prevent conception.
2. *Aloe barbadensis* Mill. (erroneously called *A. vera* Linn. in Indian literature). *English* : Socotrine or Zanzibar Aloe. *Vernacular* : *Mushabbar.*	Cultivated throughout India and even run wild as in the drier localities of South India.	Chief constituent aloin, which is glucosidic in nature, besides small quantities of an essential oil, a fixed oil, resin, gum, emodin, some anthraquinone derivatives and chrysophanic acid in some varieties [Chopra and Ghosh, 1938].	The use of the aloes or *mushab'ar* for causing purgation dates back to the 4th century B.C. The pronounced action of the drug on the large intestine induces some pelvic congestion and is therefore used as an emmenagogue. But it is contra-indicated during menstruation and must be used with caution during pregnancy and is likely to produce abortion. Indeed it has been frequently used in Europe for the purpose of procuring abortion.
3. *Ananas comosus* (Linn.) Merr. (*A. sativus* Schult. *f.*) *English* : Pine-apple plant. *Vernacular* : *Ananas, Anaras.*	Cultivated in various parts of India.	Fruit contains a digestive ferment, bromelin, which is more closely related to trypsin than to pepsin. Nothing is known regarding the presence of any poisonous chemical constituent [Wehmer, 1929-35].	Unripe fruit believed to possess emmenagogue properties. Also stated to be used to produce abortion in women as well as in animals. Even the juice of the ripe fruit held by some people to have irritant action on the uterus and to have the property of producing strong uterine contractions. The juice of leaves also stated to be used as an abortifacient [Watt, 1889-96].
4. *Annona squamosa* Linn. *English* : Custard Apple, Sweet-sop or Sugar Apple of the West Indies and America. *Vernacular* : *Ata, Sharifa, Sitaphal.*	Naturalized in several parts of India and is met with under cultivation and also as an escape.	Seeds yield an oil and a resin which contains the acrid principle [Watt, 1889-96]. Leaves and seeds found to contain an amorphous alkaloid but no glucoside [Trimurti, 1924].	When applied to *os-uteri* powdered seeds are irritant and said to produce abortion.
5. *Apium graveolens* Linn. *English* : Celery. *Vernacular* : *Ajmod, Bhutjata, Randhuni.*	Found at the foot of the North-West Himalayas and the outlying hills in the Punjab. Cultivated in different parts of India as a cold-weather crop.	A glucoside apiin [van Rijn, 1931] and an essential oil [Finnemore, 1926]. Apiole is the camphor obtainable from the essential oil of this plant.	Regarded as an emmenagogue, and is accredited with abortifacient properties.

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
6. *Areca catechu* Linn. *English* : Areca Nut Palm, Areca Palm, Betel Nut Palm, Betel-Palm, Catechu Palm, Supari Palm. *Vernacular* : *Supari.*	Extensively cultivated in moist tropical regions up to an altitude of 3,000 ft. Large scale cultivations in Southern and Western India, Assam, Bengal. Flourishes well in Malabar, Kanara and Mysore.	Nuts contain the alkaloid arecoline to the extent of about 0·1 per cent besides other alkaloids, such as guvacine, guvacoline, arecaidine and arecolidine [Henry, 1939].	'Malay women use the young green shoots as an abortifacient in early pregnancy.' [Kirtikar and Basu, 1933.]
7. *Aristolochia bracteata* Retz. *English* : Bracteated Birthwort. *Vernacular* : *Gandan, Kiramar.*	Grows on the banks of the Jumna and the Ganges, and in Bundelkhand, Sind and Konkan. In the Madras presidency it is found in the Northern Circars, the Deccan and Carnatic, on dry soils, especially the black cotton soil. Its occurrence in Bihar is doubtful.	Plant stated to contain a nauseous volatile substance and an alkaloid [Dymock, Warden and Hooper, 1890-93].	Plant accredited with emmenagogue and abortifacient properties and also used to increase the uterine contractions during labour.
8. *Aristolochia indica* Linn. *English* : Indian Birthwort, Sapsun. *Vernacular* : *Isharmul, Sapasan.*	Found throughout the low countryside of India from Nepal and the greater part of Bengal to Western and Southern India from Konkan southwards. Common in the jungles of South India among hedges and bushes.	Roots contain a phytosterol glucoside, an alkaloid aristolochine, a bitter substance isoaristolochic acid, and an essential oil containing a sesquiterpene ishwarene, a sesquiterpene ketone ishwarone, a sesquiterpene alcohol ishwarol, etc. [Krishnaswamy, Manjunath and Rao, 1935 : Rao, Manjunath and Menon, 1935].	Plant said to be used to procure abortion [Watt, 1889-96].
9. *Artemisia vulgaris* Linn. *English* : Flea-bane, Indian Wormwood, Motherwort, Mugwort. *Vernacular* : *Nagdona, Samri.*	A gregarious shrub found throughout the mountain tracts of India, especially between 5,000 and 12,000 ft. above sea level.	Essential oil containing α thujone, borneol, etc. [Finnemore, 1926].	In large doses it causes violent contractions of the uterus, labour-like pains, prolapse and rupture of the uterus, abortion, metorrhagia and increase in lochial discharges.
10. *Calotropis gigantea* (Linn.) Dryand. (*C. gigantea* R. Br.) *Vernacular* : *Ak, Akund, Madar.*	Frequently met with throughout India as a weed on fallow land and in waste ground except in the Punjab where its occurrence is doubtful.	Fibre contains a toxic bitter substance [Matthes and Streicher, 1913]. Milky juice found to contain a proteolytic enzyme similar to papain [Basu and Nath, 1933 ; *Ibid*, 1938]. Roots contain a guttapercha-like substance (*madar* alban) and a bitter yellow resinous substance [Sharma, 1934 ; Hill and Sarkar, 1915].	In India the juice of these plants used as an abortifacient, and for this purpose is either given internally or painted over the mouth of the womb, through the vagina, when it sets up intense irritation.
11. *Calotropis procera* (Linn.) Dryand. (C. procera R. Br.) *Vernacular* : *Ak, Akund, Madar.*	Found more or less throughout India in warm and dry places from the North-West Frontier Province and the Punjab to Western, Central and Southern India. Occurs abundantly in Sub-Himalayan tracts and the adjacent plains in the North-West.	Milky juice contains a proteolytic enzyme and a toxic substance [Gerber and Flourens, 1913]. Also contains a highly active resin [Gerber and Flourens, 1912]. Root bark contains a bitter yellow-resin but no alkaloid [Sharma, 1934].	See under *C. gigantea* (Linn.) Dryand.

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
12. ***Carica papaya*** Linn. ***English*** : Melon Tree, Papaw, Papaya, Papeta, Paupau, Pawpaw, Tree Melon. ***Vernacular*** : *Arand-kharbuza, Papaya, Papita.*	Extensively cultivated throughout India. Does not grow well in the drier parts of India but thrives well where rainfall is high and climate hot.	Latex or the milky juice contains a proteolytic enzyme papain and also a milk-curdling ferment. Leaves contain a glucoside carposide and an alkaloid carpaine [van Rijn, 1897]. Milky juice, bark, roots and seeds contain only traces of carpaine [Greshoff 1890 ; van Rijn, 1893].	A belief in the powerful emmenagogue properties of the seeds prevails among all classes of people in Southern India, who assert that if a pregnant woman partakes of them even in moderate quantities, abortion will result.
13. ***Celastrus paniculatus*** Willd. ***English*** : Black-oil plant. ***Vernacular*** : *Malkungani, Valuluvai.*	Found in tropical and sub-tropical Himalayas, the Punjab and throughout the hilly districts of India ascending to 4,000 ft. above sea level.	Seeds yield on expression a fatty oil (Celastar oil) and by destructive distillation an empyreumatic oil [Wehmer, 1929-31].	Seeds said to be used to procure abortion though nothing known regarding their abortifacient properties.
14. ***Cinchona calisaya*** Wedd. ***English*** : Bolivian Bark, Calisaya Bark, Yellow Bark. ***Vernacular*** : *Burak, Shurappattai.*	Cultivated in Sikkim and Nilgiris.	A number of alkaloids obtained from the bark of which the best known are quinine, quinidine, cinchonine, cinchonidine, besides a few free organic acids, tannins, some neutral substances, colouring matters, traces of volatile oils, gum, starch and other vegetable matters.	Unstriated muscle in the mammals tends to contract under the influence of quinine, the action being especially marked on the uterus which is thrown into rhythmical contraction. Abortion occurs occasionallly after its use in malaria, while in other cases labour pains may be induced.
15. ***Cinnamomum camphora*** Nees & Eberm. ***English*** : Camphor laurel, Camphor Tree. ***Vernacular*** : *Kagur, Kappur, Kappuram.*	Indigenous to Formosa, China and Japan ; planted in some gardens up to an altitude of 4,000 ft. in the North-West Himalayas.	Leaves, stems and fruits contain an essential oil (Camphor oil) with 50-55 per cent of camphor [Wehmer, 1929-35].	In India camphor is often administered along with plantains to produce abortion ; about 20 grains are believed to be sufficient for the purpose [Watt., 1889-96].
16. ***Citrullus colocynthis*** Schrad. ***English*** : Bitter Apple, Bitter Cucumber, Colocynth, Coloquintide. ***Vernacular*** : *Indrayan, Makal, Tumma.*	Found wild in waste lands throughout India, particularly in the North-West, Central and South India.	Fruit pulp of colocynth contains traces of an essential oil, a dihydric alcohol designated as citrullol, a weekly basic alkaloidal principle, and some resinous material. Amount of glucosidic substance contained in the fruit is extremely small [Wehmer, 1929-35].	Taylor cites the case of an adult female who took 120 grains of the powder in order to produce abortion, and died in fifty hours. [Waddell, 1928].
17. ***Crocus sativus*** Linn. ***English*** : Saffron. ***Vernacular*** : *Jafran, Kesar, Zafran.*	Cultivated at an altitude of 5,000 to 6,000 ft. in Pampur, Kashmir.	Saffron contains a glucoside, a bitter substance and an essential oil [Wehmer, 1929-35]. Bulbs contain a saponin [Watt and Breyer-Barndwijk, 1932].	Stated to have been used as an abortifacient, but apparently lacks this action and is practically non-toxic [Sollmann, 1936].
18. ***Cucumis trigonus*** Roxb. ***Vernacular*** : *Bislambhi, Gomuk, Jangli-indrayan, Karit.*	Found throughout the greater part of India.	Fruit contains colocynthin or a substance of a similar nature [Naylor and Chappel, 1907].	Bitter pulp used as substitute for colocynth and is a drastic purgative. Waddell [1928] mentions a case which was reported to the Bombay Chemical Analysers' office in 1833, in which it was stated that the root of this plant had been administered for the purpose or procuring abortion.

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
19. *Cuscuta reflexa* Roxb. *English :* Dodder. *Vernacular : Akash bel, Amarvel, Imalbel, Kashus, Zarbuti.*	Occurs as a parasite throughout the plains of India ascending up to 8,000 ft. above sea level : often very destructive to small trees and shrubs if left to itself.	Plant found to contain the colouring matter cuscutin [Agarwal and Dutta, 1935] but nothing of pharmacological importance isolated.	The *dais* (Country midwives) in the Punjab have a great faith in a decoction of this plant as an abortifacient. A decoction made in boiling water from 180 grains of this plant is said to produce depression with nausea and vomiting, followed by abortion [Dulip Singh, 1885].
20. *Daucus carota* Linn. *English :* Carrot. *Vernacular : Gajar.*	Cultivated throughout India as an article of food.	Fruit of the cultivated carrot yields 1 to 1·5 per cent of an essential oil, and a crystalline body named daucol [Finnemore, 1926].	Seeds popularly regarded as a powerful abortifacient, and numerous cases of abortion, following their internal administration, are on record. More precise information is, however, wanted with regard to their alleged abortifacient properties.
21. *Dolichandrone falcata* Seem. *Vernacular : Bhersing, Kanseri, Mendel.*	Found in Rajputana, Bundelkhand, Bihar, Central Provinces, Berar, Konkan, Deccan, Mysore and most districts of the Madras Presidency in dry deciduous forests and often on rocky slopes.	....	Plant reputed to be an abortifacient though its specific abortifacient power not known.
22. *Euphorbia tirucalli* Linn. *English :* Milk bush, Milk hedge, Indian Tree Spurge. *Vernacular : Lanke-sij, Nevli, Sehund, Shir-thor.*	A native of Africa but become naturalized in many places in India. Often grown as a hedge or occasionally as a roadside tree.	Milky juice contains about 20 per cent of resins [Wehmer, 1929-35].	Twigs of this plant are stated to be inserted into the vagina or uterus for procuring abortion.
23. *Excoecaria agallocha* Linn. *English :* Blinding Tree. *Vernacular : Gaugwa, Geon, Haro.*	Found in tidal forests and swamps on all the coasts of India.	....	Dr C. R. Dutt, Asstt. Surgeon, Patuakhali, Bengal, reported to the authors a case wherein the fresh juice of the plant was given to a pregnant woman carrying five months with a view to procure abortion, with successful results.
24. *Garcinia morella* Desr. *English :* Gamboge Tree. *Vernacular : Devanahuli, Jarige, Pesupuvarna, Tamal.*	An evergreen tree found in the forests of Eastern Bengal, the Khasia Mountains and the Western Ghats from Kanara and Mysore to Travancore.	Gamboge contains 70-80 per cent of resin, 15-20 per cent of gums and a small quantity of vegetable debris. Resin consists of several resinic acids named as 'garcinolic acid', also esters and neutral resene [Allen, 1923-33]. These acids form readily soluble compounds with alkalis and thus become active in the intestine. Effects resemble those of colocynth.	Gum-resin used as an abortifacinet. In doses of one to five grains it has a purgative action, but cases are on record where large doses, such as of one drachm have resulted in death.

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
25. *Gossypium herbaceum* Linn. *English :* Cotton Plant. *Vernacular : Kapas, Rui.*	Cultivated throughout the hotter regions of India.	Root-bark contains a pale yellow or colourless acid resin to the extent of about 8 per cent [British Pharmaceutical Codex, 1934], and also gossypol [Sollmann, 1926].	Attention appears to have been first drawn to the emmenagogue property of the root-bark from the observation of Dr Bouchelle of Missisipi who stated that it was used by negro women to procure abortion. There appears to be little doubt that it acts like ergot upon the uterus, and is useful in dysmenorrhoea and suppression of the menses when produced by cold [Watt, 1889-96].
26. *Gloriosa superba* Linn. *English :* Glory Lily. *Vernacular : Agnisikhe, Bachnag, Bisha, Dudhiorachnag, Garbhaghatini Kalihari, Kathari, Kulhari.*	Found throughout India ascending up to an altitude of 7,000 ft. on the hills. Common in Mysore State.	Roots contain a bitter principle [Warden, 1880]. Tubers contain an enzyme, an alkaloid colchicine and two other crystalline bases. Toxic properties of the tubers due essentially to the colchicine present.	It constitutes one of the seven minor poisons of Sanskrit writers. Its Sanskrit synonym 'garbhaghatini' means 'the drug that causes abortion'. The tuberous roots are indeed, popularly believed in India to be highly poisonous and are used to some extent at least to commit suicide and procure abortion [Watt, 1889-96].
27. *Lepidium sativum* Linn. *English :* Cress. *Vernacular : Halim.*	Cultivated throughout India	Seeds contain an essential oil [Finnemore, 1926].	Seeds used in indigenous medicine. Over doses believed to produce abortion.
28. *Momordica charantia* Linn. *English :* Carilla Fruit. *Vernacular : Karela.*	Largely cultivated throughout India for its young fruits, of which there are several cultivated forms, differing in shape and size.	Leaves contain a bitter substance 'momordicin' 'resins', two resin acids, etc. [Wehmer, 1929-35]. Plant contains about 0·038 per cent of an alkaloid [Luis Torres Diaz, 1936] and the seeds yield about 32 per cent of a purgative oil [Freise, 1929].	In India, the roots stated to be used successfully for procuring abortion [Waddel, 1928]. A case wherein abortion was produced at the seventh month by swallowing a decoction of the roots of this plant has been reported [Bomb. Chem. Analyser's Rep., 1879-80].
29. *Momordica tuberosa* Cogn. (*M. cymbalaria* Fenzl *ex* Naud.) *Vernacular : Kadavanchi.*	Found in the western parts of India from Sattara district in the north down to Tinnevelly in the South.	Tubers said to contain a bitter glucoside [Dymock, Warden and Hooper, 1890-93].	Whole plant acrid and the ovoid tuberous roots reported to have been used in procuring abortion, a decoction being administered for this purpose [Watt, 1889-96].
30. *Moringa oleifera* Lam. (*M. pterygosperma* Gærtn.) *English :* Drum-stick Tree, Horse-radish Tree. *Vernacular : Guggala, Karunjanam, Mangai, Murunga, Segata, Suhajana.*	Grows wild in the Sub-Himalayan tract from the Chenab to Oudh, and is commonly cultivated throughout India.	The root bark contains 0·105 per cent of alkaloids, an essential oil with a very pungent smell, a crystalline base termed moringine which is physiologically inert, and a liquid base, moringinine, which is physiologically active. [Ghosh, Chopra and Dutt, 1935].	Gum said to procure abortion but reliable information on this point lacking. It may be possible to use it as a tent to dilate the *os uteri*, as it is tough and swells rapidly when it draws moisture [Watt, 1889-96].

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
31. *Nerium indicum* Mill. (*N. odorum* Soland.) *English :* Indian olaender, Sweet-scented Olaender. *Vernacular :* *Ganira*, *Kaner*, *Khar-zahrah*, *Sum-el-himar*.	Found in the Himalayas from Kashmir to Nepal up to an altitude of 6,500 ft, on the Punjab Salt Range extending westerds to Baluchistan, and also in Central India. Cultivated throughout India in gardens and is apparently wild in South India and in the Bombay Presidency along banks of streams.	Roots, bark and seeds contain the toxic principles neriodorin, neriodorein and karabin. [van Rijn, 1931 ; Bose, 1901].	Several suicidal, homicidal and abortion cases are on record in India from the use of this plant. Commonly used for procuring criminal abortion both by local application and internal administration. In fact the poisonous properties are so well known in India that it is a proverbial taunt among females to say 'Go and eat the *kaner* root'.
32. *Nigella sativa* Linn. *English :* Small Fennel, Black Cummin. *Vernacular :* *Kali - jira*, *Kalonji*, *Mugrela*.	Cultivated extensively in many parts of India for its seeds.	Seeds stated to contain 0·5 to 1·4 per cent of an essential oil and a saponin-like glucoside, melanthin [Wehmer, 1929-35].	Seeds used as emmenagogues in Europe; in doses of 10 to 20 grains they possess a well-marked emmenagogue action in dysmenorrhœa, and in larger doses produce abortion [Watt, 1889-96].
33. *Peganum harmala* Linn. *English :* Harmal, Syrian Rue, Wild Rue. *Vernacular .* *Harmal*, *Kaladana*, *Spalanai*, *Spanda*.	Very common in the drier waste places and fields of Baluchistan, Waziristan, Kurrum Valley, Sind, Cutch, the Punjab, Kashmir, Delhi, the United Provinces, Bihar, Konkan and the Western Deccan.	Seeds found to contain three alkaloids — harmine, harmaline and harmalol to the extent of 2·5 to 3 per cent. Recently another alkaloid, peganine, isolated from the seeds which is stated to be identical with vasicine, the alkaloid found in *Adhatoda vasica* Nees. [Henry, 1939]. They also contain a soft resin with deep carmine-like colour having a heavy narcotic odour resembling that of the resin of *Cannabis sativa* Linn. [Watt, 1889-96].	Seeds considered narcotic nauseant, emetic and emmenagogue. Gopal, as quoted by Watt [1889-96] found that an infusion or tincture acted as a mild emmenagogue. He reported that the plant was sometimes employed by Indian midwives to procure abortion and believed that the drug has properties similar to those of ergot, savine and rue.
34. *Plumbago indica* Linn. (*P. rosea Linn.*). *English :* Fire Plant, Officinal Leadwort, Rosy-flowered Leadwort. *Vernacular :* *Chitra*, *Chittermul*, *Lal-chita*, *Lal-chitarak*.	Largely cultivated in gardens and stated to occur in a state of nature in the Bengal Duars, Sikkim and Khasia. Also found as an escape in Southern India.	Root-bark contains the toxic substance plumbagin but no alkaloid [Katti and Patwardhan, 1932].	Root mentioned by ancient Sanskrit and Mohammadan writers as an abortifacient and vesicant. It is commonly used in India for producing abortion. With this object it is sometimes given internally and has more than once been detected as plumbagin in pills stated to have been administered for this purpose. Usually, however, it is employed as a local irritant application to the *os-uteri*, a portion of the scraped root or twig of the plant being pushed into the vagina, and sometimes even into the uterus. In other cases the end of an abortion stick is covered with a paste made from the powdered roots. Death not infrequently results from the introduction of this highly acrid agent if used in any of the above ways.

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
35. *Plumbago zeylanica* Linn. *English :* White-flowered Leadwort. *Vernacular :* *Chitra, Chitramula, Safed-chita, Safed-chitarak.*	Largely cultivated in gardens throughout India and often seen as an escape. Grows wild in south India and probably also in Bengal.	Roots contain plumbagin which is absent in the leaves and stems [Roy and Dutt, 1928].	Possesses properties similar to those of *P. indica* Linn, and both used for the same purposes.
36. *Plumeria acuminata* Ait. (*P. acutifolia* Poir.). *English :* Frangipani, Jasmin Tree, Pagoda Tree. *Vernacular :* *Arali, Champa, Gobur-champ, Golainchi, Gosampige, Gulchin.*	Cultivated as an ornamental tree throughout India and became naturalized in many places.	Bark contains a bitter glucoside named plumierid which changes to plumieric acid after treatment with alkaline solutions even in cold [van Rijn, 1931]. Milky juice contains plumeric acid, as a calcium salt [Wehmer, 1929-35].	Root a violent cathartic and blunt-ended branches used to procure abortion [Watt, 1889-96].
37. *Randia dumetorum* Lam. *Vernacular :* *Ghela, Maindal, Menphal, Rara.*	Found in the Sub-Himalayan tract from Rawalpindi district up to 4,000 ft. Extends southwards to Chittagong.	Fruits contain a saponin in the pericarp, a glucosidic saponin in the pulp and seeds traces of an alkaloid [Vogtherr, 1894]. An essential oil also present [Chopra, 1933].	Pulp of the fruit said to be used sometimes as an abortifacient [Watt, 1889-96].
38. *Rubus moluccanus* Linn. *Vernacular :* *Katsol, Sufokji.*	Common in many parts of central and eastern tropical and temperate Himalayas from Kumaon to Sikkim at altitudes of 3,000 ft. to 7,000 ft. Occurs also in Assam and in the Khasia Hills at altitudes of 3,000 to 5,000 ft. above sea level, and in the Ghats from Bombay southwards.		According to Rumphius the leaves are abortifacient and a powerful emmenagogue [Watt, 1889-96].
39. *Ruta graveolens* Linn., var. *angustifolia* Hook. *f.* *English :* Ave Grace, Common Rue, Countryman's Treacle, Garden Rue, Herb of Grace, Herb-repentance, Herb of repentance. *Vernacular :* *Pismarum, Sadab, Satapa, Satari, Sudah.*	Cultivated in Indian gardens for the medicinal properties of its leaves and seeds.	A volatile oil (oil of rue) obtained to the extent of about 0·06 per cent by distilling the fresh herb in water. A glucoside rutin and a coumarin-like odoriferous principle also isolated from the plant [Watt and Breyer-Brandwijk, 1932].	Oil from *Ruta graveolens* Linn. used for several purposes in western medicine. Given internally it acts as an emmenagogue in doses of 2 to 5 drops. In larger doses, however, it acts as an abortifacient and produces irritant symptoms. Indian variety appears to be a perfect substitute and finds similar uses in indigenous medicine. The oil and the herb frequently employed to produce criminal abortion both in Europe and India though in ordinary doses it appears to have no effect on the uterus.
40. *Salicornia brachiata* Roxb. *Vernacular :* *Mechul, Kattumari, Umari.*	Found in Gujerat, Kathiawar, Western and Eastern Coast of the Madras Presidency, Sundarbans, etc., on saline marshes or ground covered by the tides.		Ash considered to have emmenagogue and abortifacient properties [Kirtikar and Basu, 1933].

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
41. *Sapindus trifoliatus* Linn. *English :* Soap Nut Tree of South India. *Vernacular :* *Antala, Arishta, Kottaimaram, Ritha.*	A common tree about the villages in South and West India; also cultivated in Bengal and planted elsewhere also.	Pericarp contains a fairly large quantity of saponins, about 4·5 per cent [Wehmer, 1929-35].	Nut stated to be used for procuring abortion.
42. *Semecarpus anacardium* Linn. *f.* *English :* Marking-nut tree. *Vernacular : Bhela, Bhilaran, Bhilawa.*	Found in the Sub-Himalayan tract from Bias eastwards, ascending in the outer hills up to 3,500 ft. Assam, Khasia Hills, Chittagong, Central India, Gujerat, Konkan, Southern Mahratta Country, Kanara and in deciduous forests of all districts in the Madras Presidency.	Juice of the pericarp contains (*a*) semecarpol, (*b*) bhilawanol, and (*c*) a tarry, non-volatile corrosive residue forming about 18 per cent of the nut [Pillay and Siddiqui, 1931].	Externally a powerful counter-irritant and vesicant. Applied locally for procuring criminal abortion.
43. *Sesamum orientale* Linn. (*S. indicum Linn.*). *English :* Gingelly-oil Plant, Sesame. *Vernacular : Gingli, Kala-til, Krishna-til, Til.*	Largely cultivated throughout India, being grown as an autumn or even as a winter crop in the warmer parts of the country (the truly tropical areas), and as a summer one in the colder areas.	Oil from the seeds contains about 1 per cent of *sesamin* and *sesamolin*. The latter breaks up into a phenolic substance sesamol and another substance samin [Andriani, 1928].	Kobert [1906] states that the seeds have been used since olden times as emmenagogue and abortive, an opinion which has also been expressed by some writers in India. This view, however, seems to be incorrect, judging from the extent to which it is often eaten by Indian women, as for example during the 'bhugga' festival of the Hindus in the Punjab. The existence of any such belief among Indian ladies is unknown.
44. *Stachytarpheta jamaicensis* (Linn.), Vahl, var. *indica* H. J. Lam (*S. indica* Vahl). *English :* Aarons Rod. *Vernacular :* *Jalagali, Kariyu Harni, Sinainaivirunji.*	Found practically throughout India from the Punjab and Sylhet to Travancore. Common as a weed. Sometimes grown in gardens.	Said to contain a glucosidic substance [Wehmer, 1929-35].	Not put to any use in India but stated by Pammel [1911] to have abortifacient properties.
45. *Taxus baccata* Linn. *English :* Yew. *Vernacular : Barini, Birini, Postal, Thuna.*	Met with in temperate Himalayas at altitudes of 6,000 ft. to 11,000 ft., and in the Khasia Hills at altitudes of 5,000 ft.	Leaves, shoots, and 'fruits' contain a toxic alkaloid taxine [Henry, 1939]. Sap acrid and contains a volatile oil [Lander, 1926]. Leaves contain much formic acid [Blyth, 1920] and also the glucoside taxicatin [Lefebvre, 1907] and small amounts of ephedrine [Gutland and Virden, 1931].	Leaves occasionally employed by ignorant people to procure abortion. [Watt, 1889-96].
46. *Thevetia peruviana* (Pers.) Merr. (*T. nereifolia* Juss. *ex* Steud.). *English :* Bastard Oleander, Exile Oleander, Yellow Oleander. *Vernacular : Chinakurab Kolkephul, Pila-kaner, Zard-kaner.*	Originally a native of America and West Indies, now almost naturalized in some places. Scarcely a garden in the plains without a few shrubs, if not a hedge.	A fatty oil constituting more than 62 per cent of the kernel and four crystalline substances—phytosterolin, ahouain, kokilphin and thevetin [Chen and Chen, 1934]. Roots also found to contain thevetin [Arnold Middleton and Chen, 1935].	Seeds long known to be highly poisonous and commonly used by women as an abortifacient, especially in Bengal and neighbouring provinces.

APPENDIX—*concld.*

Name of plant	Distribution	Constituents	Remarks
47. *Trianthema pentandra* Linn. *Vernacular : Bishkapra, Itsit.*	A common weed growing on waste lands in the plains of the Punjab, Sind and North-West India.		Plant believed to cause abortion and apt to produce diarrhœa and paralysis [Stewart, 1869].
48. *Trianthema portulacastrum* Linn. (*T. monogyna* Linn.). *English :* Horse Purslane. *Vernacular : Bishkapra, Itsit, Sabuni, Swetpunarnava.*	Common throughout India .	The authors have found the presence of water soluble bases and potassium salts in the plant.	Roots stated to have cathartic and irritant properties and used to procure abortion. [Dymock, Warden and Hooper, 1890-93].
49. *Urena lobata* Linn. . *Vernacular : Bachita, Ban-ochra, Vana-bhenda.*	A common herb, generally distributed throughout the hotter parts of India, very frequently in waste places, and in the bamboo and mango clumps of Bengal.	Seeds contain an enzyme, urease [Wehmer, 1929-31].	A private communication from Dr R. C. Muirhead Thomson of the Tocklai Experimental Station, Cinnamara, Upper Assam to the authors states that root of this plant are supposed to be widely used for procuring abortion. A short piece of the root is inserted into the vagina and left there for several hours. Said to be widely used by the Assamese and may possibly be used by the tea garden coolies too.
50. *Withania somnifera* Dun. *Vernacular : Asgand, Asvaganda.*	Found throughout the drier parts of India, especially in waste places, ascending to 5,000 ft. on the Himalayas.	Root contains 0·006 per cent of a light brown and pungent volatile oil and an amorphous alkaloidal principle. Leaf and stem yielded traces of volatile oil, tannin, a considerable amount of potassium nitrate, etc. [Power and Salway, 1911]. Besides the above alkaloid three other bases isolated from the resin obtained from the plant [Majumdar and Guha, 1933].	Root occasionally employed in the Punjab to effect criminal abortion, and the same practice believed to be common in Sind [Stewart, 1869]. Pammel [1911] also states that the plant has abortifacient properties.

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THE EFFECT OF CERTAIN SOIL FACTORS ON THE YIELD OF MAJOR CROPS IN THE PUNJAB

II. RICE

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(With 17 text-figures)

Although several attempts had been made in the past to work out statistical correlations between the yield of agricultural crops with certain meteorological factors, little attention had been paid to correlate the yield with main characteristics of soils bearing those crops. The authors in a previous publication [1941] presented the analyses of soils taken from wheat areas in the various districts of the Punjab and their statistical relationships with the figures for the yield of wheat. That previous work brought out significant correlations between the manganese and available phosphate contents of those soils and the yield of wheat and was of sufficient interest to justify the extension of work on those lines to soils representing other major agricultural crops of the Province. The present study relates to the effect of certain soil characteristics on the yield of rice.

Collection of soil samples

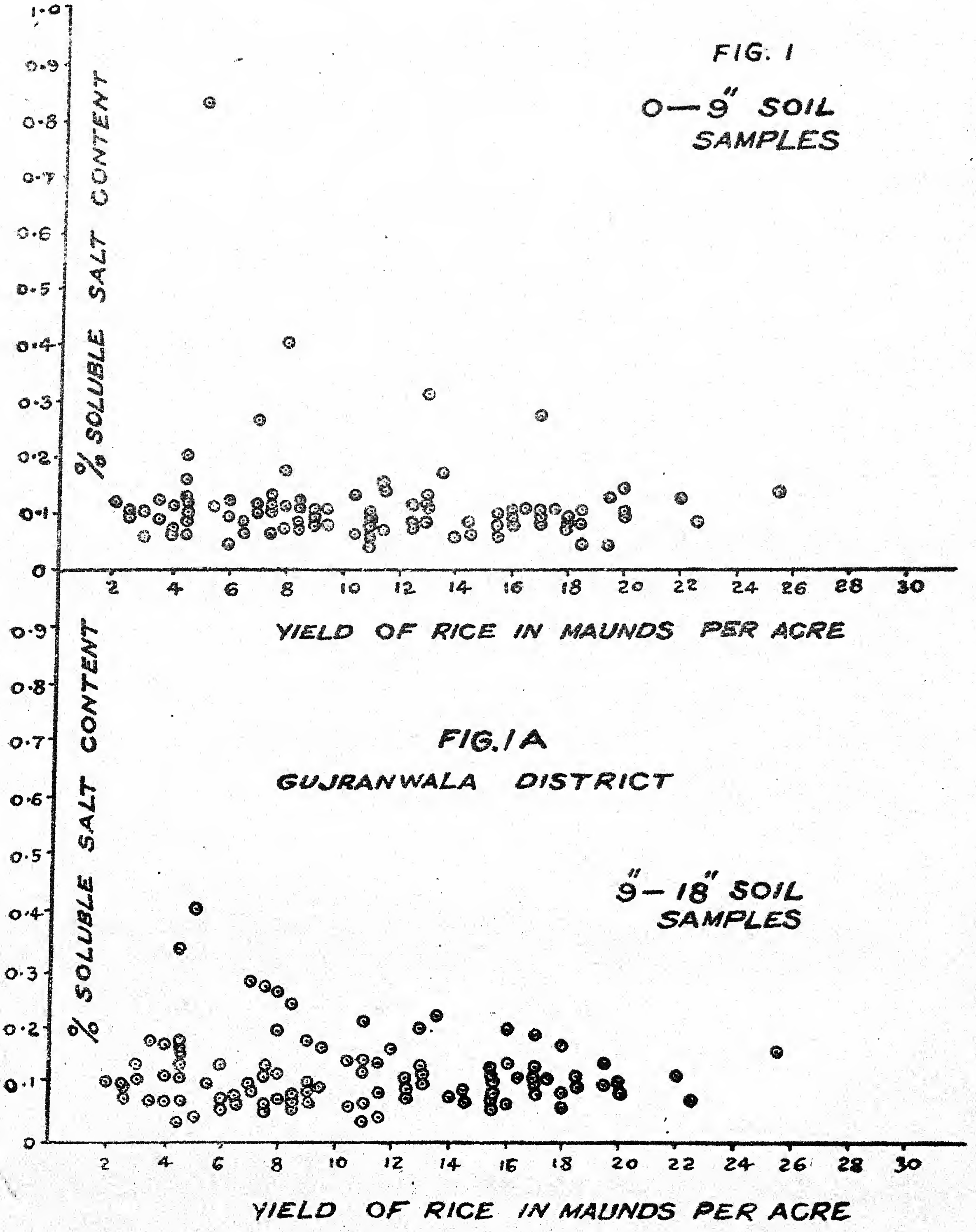
For the present investigation soil samples were taken from a large number of fields in the two predominantly rice growing districts of the Province, viz. Gujranwala and Sheikhupura. The sampling was restricted to the top 18 inches soil at each site. The soil profile was exposed to that depth near the centre of each field to be sampled and two samples collected, one from top nine inches representing the depth mainly affected during ploughing and the other from the next nine inches which usually contains the major part of the root system of the crop. Thd yields of rice, expressed in maunds (equivalent to 82 lb.) per acre, of all fields sampled were ascertained with the help of canal *patwaris* and local zemindars. As far as possible, the fields selected for this study were normal from the point of view of irrigation applied, crop rotation, etc., so that the difference in the crop yields could be attributed mainly to differences in certain characteristics of soils of those sites.

Experimental

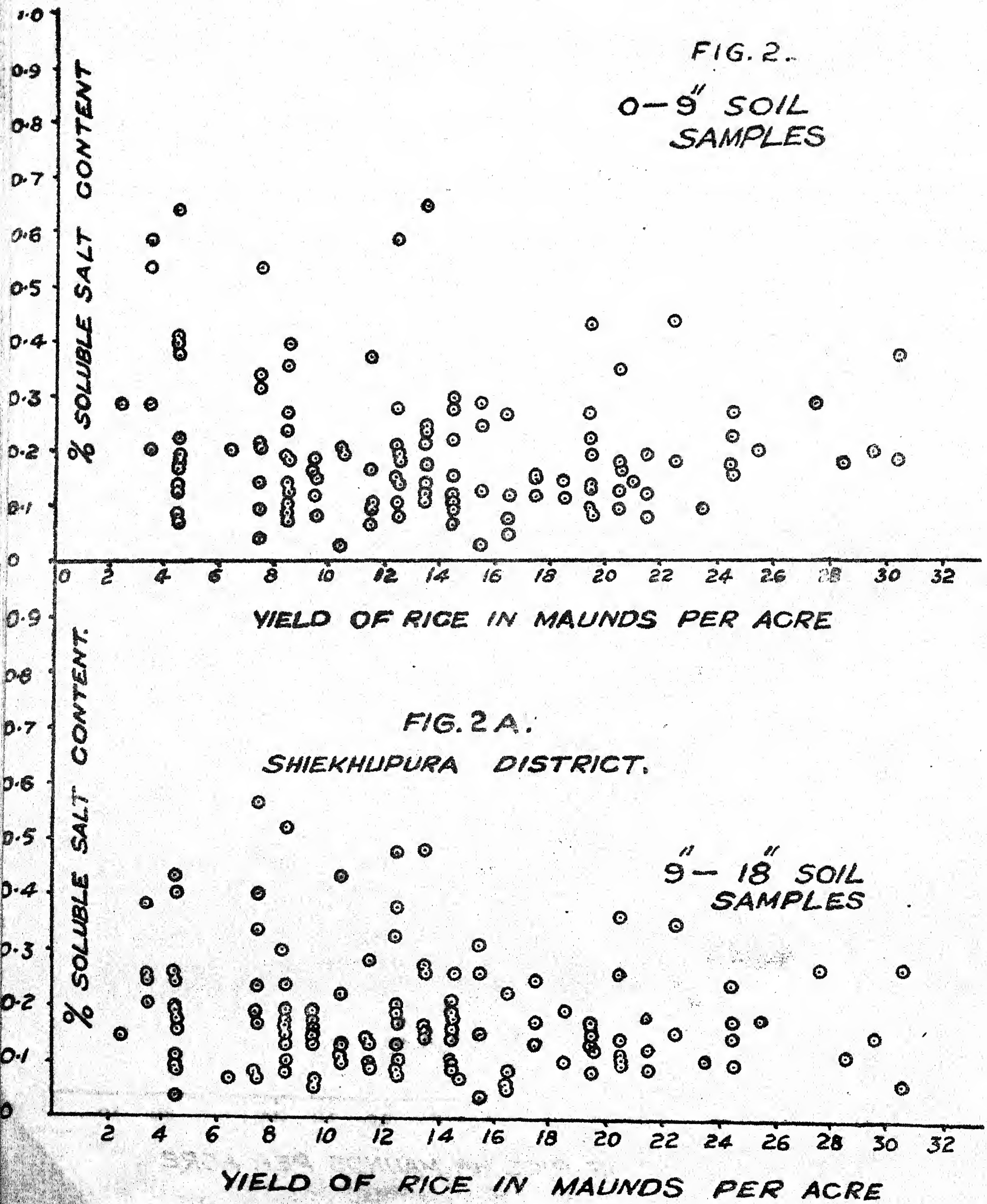
The following is a brief description of the technique adopted for the analysis of the soil samples :

The soluble salt content was determined by evaporating an aliquot of water extracts prepared from 1 : 5 soil-water suspensions. The *p*H of 1 : 5 soil-water suspensions were determined with glass electrode [Hoon and Taylor, 1931]. The total manganese content was determined by the bismuthate method as recommended by the Bureau of Soil Science [1937]. The available phosphates were extracted from soils with carbon dioxide [Puri and Asghar, 1936] colour developed according to Chapman [1932] and matched against colour standards employing Bolton and Williams' photoelectric colorimeter. Boron was extracted from soils with hot water, quinalizarin employed for developing colour [Smith, 1935] and estimated colorimetrically. Total nitrogen was determined by Kjeldahl's method as modified by Bal [1925]. The calcium carbonate content was determined by titration with sulphuric acid [Puri, 1930]. The exchangeable bases were determined by the usual methods. The degree of alkalization was calculated from the contents of the main exchangeable bases [Puri, 1933].

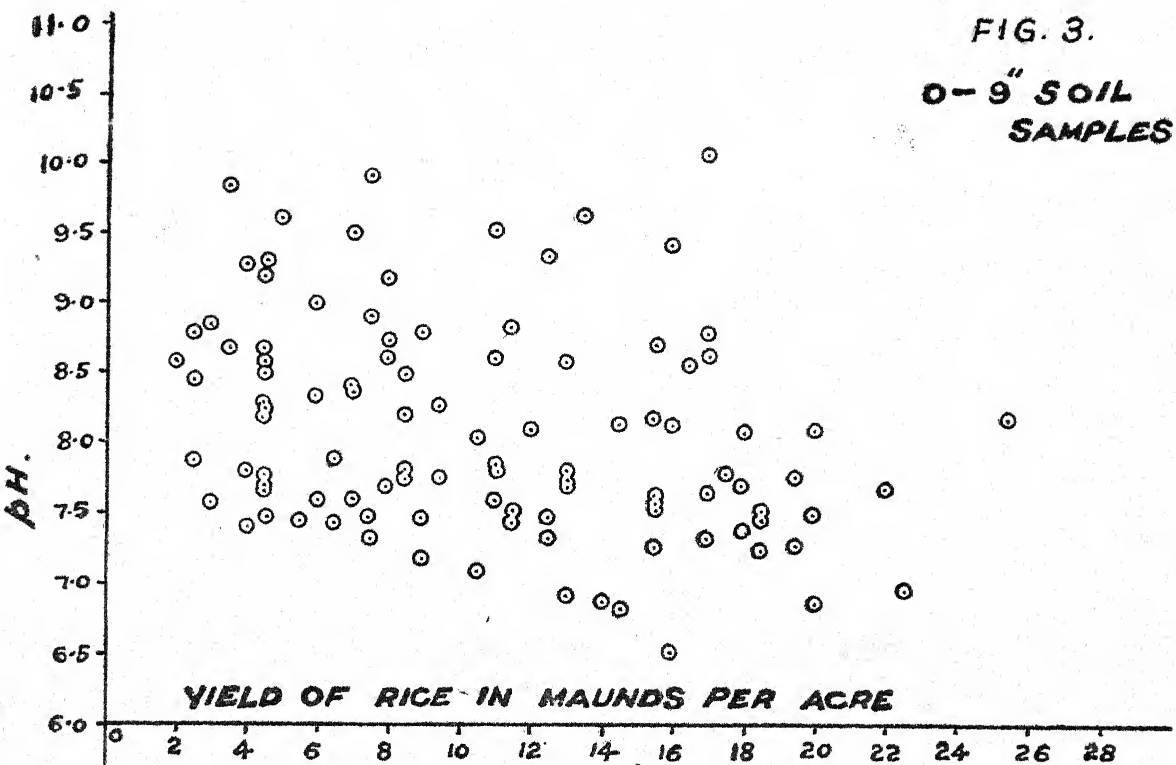
The results of the various analyses have been represented diagramatically against the yield of rice in maunds separately for the top nine inches (Figs. 1-16) and the second nine inches soil samples (Figs. 1A-16A) of the two districts.

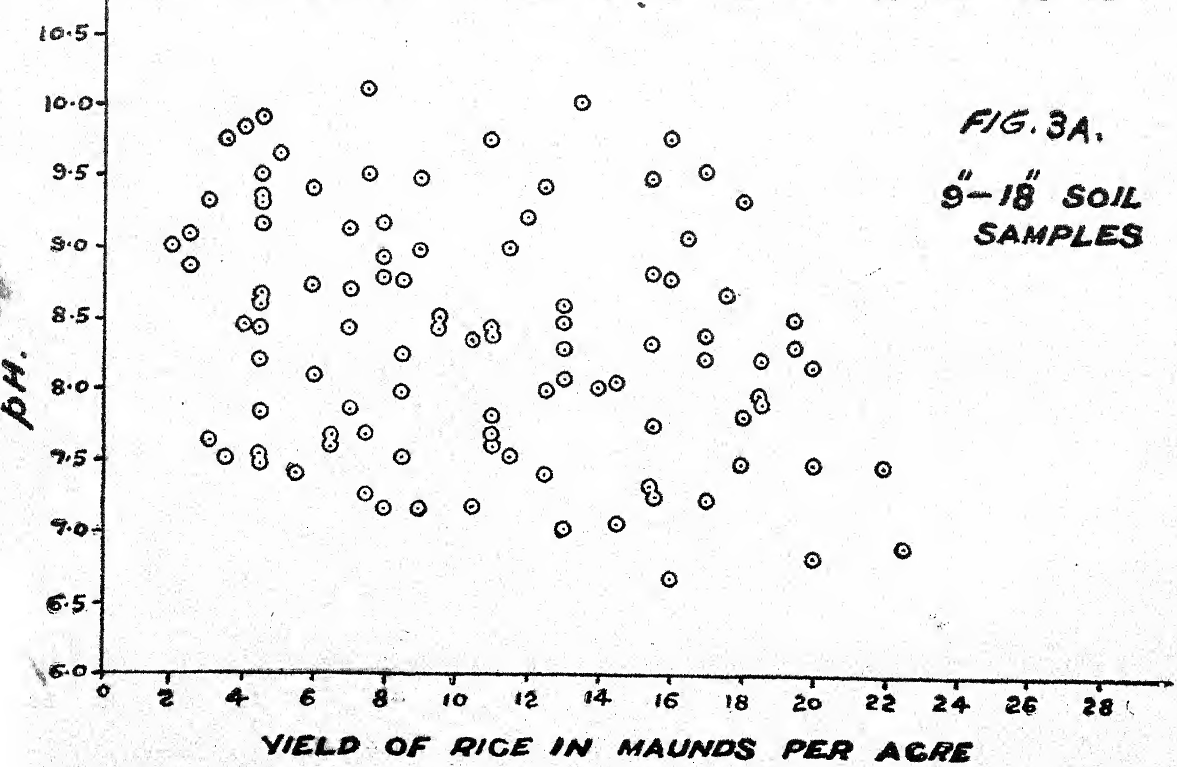


FIGS. 1 and 1A. Soluble salt content of soils of Gujranwala district in relation to the yield of rice

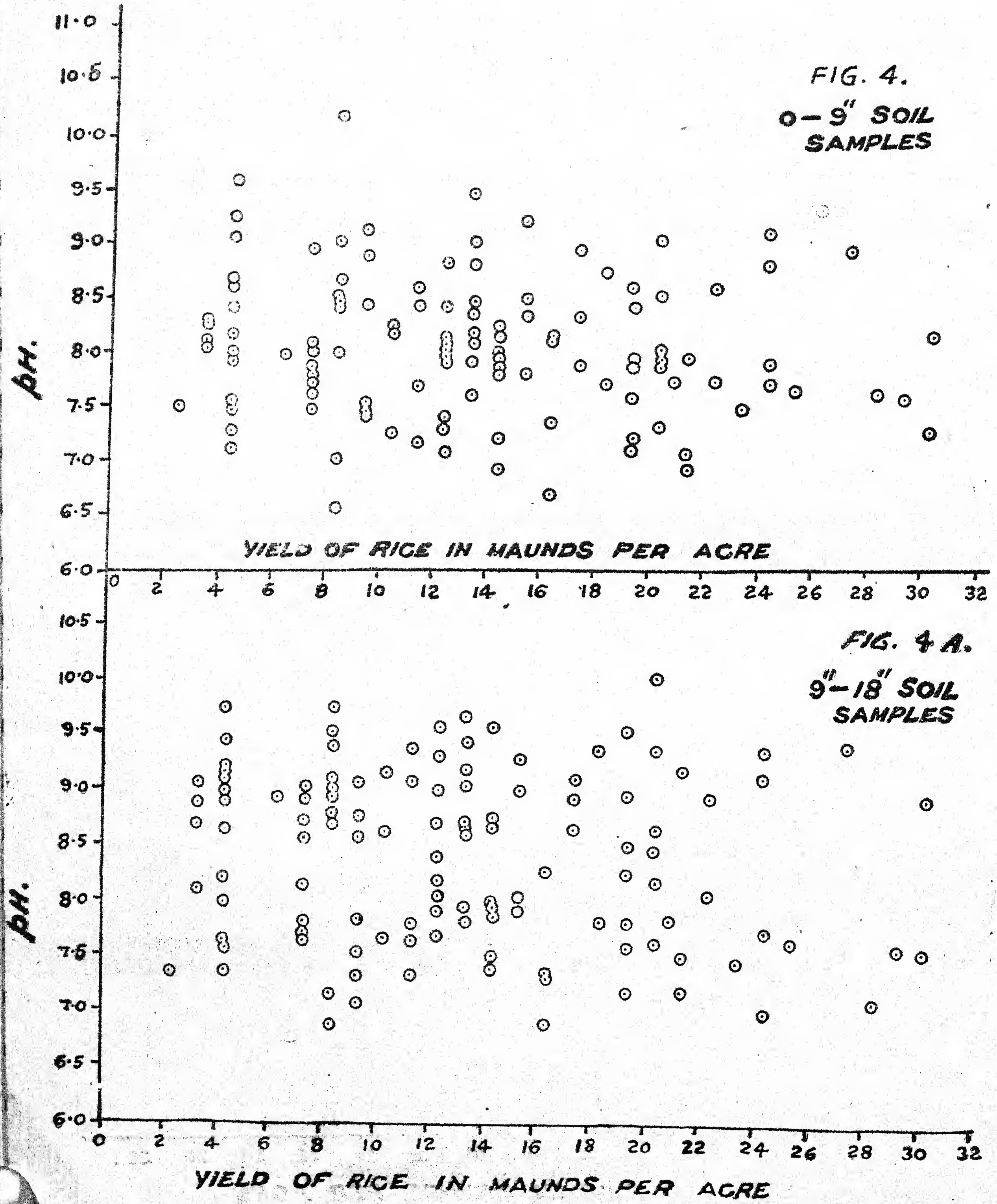


FIGS. 2 and 2A. Soluble salt content of soils of Sheikhupura district in relation to the yield of rice

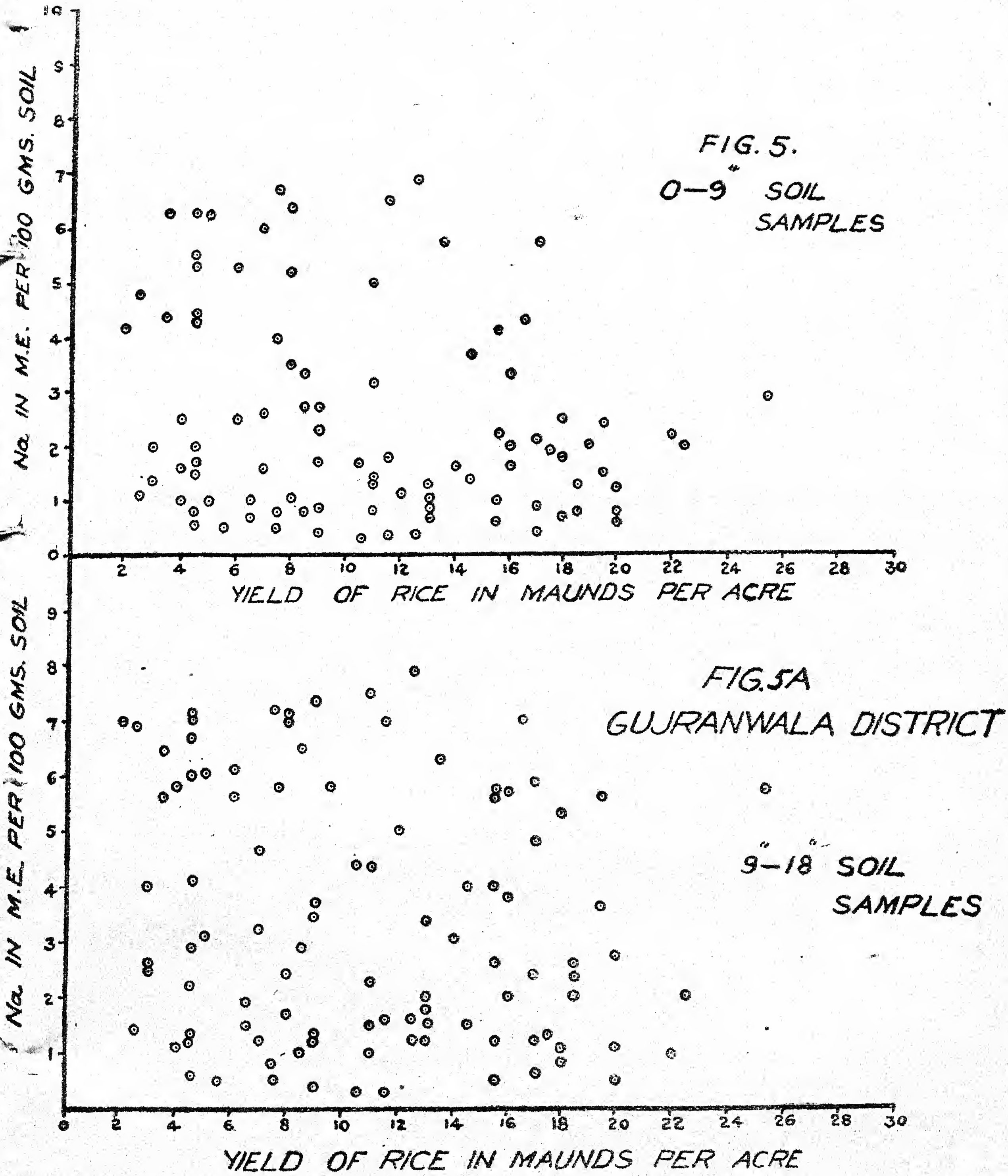




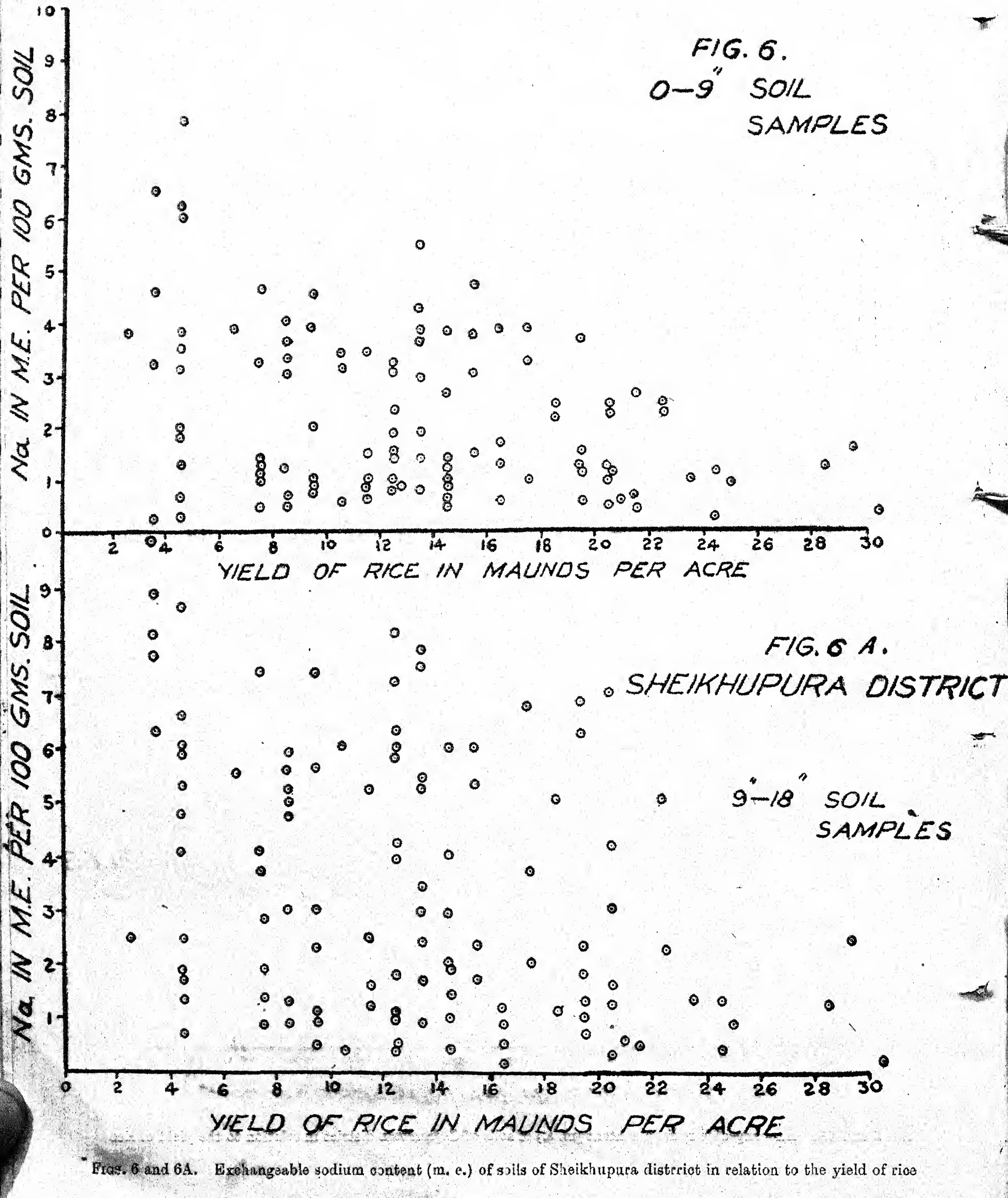
FIGS. 3 and 3A. pH of soils of Gujranwala district in relation to the yield of rice



FIGS. 4 and 4A. pH of soils of Sheikhupura district in relation to the yield of rice



FIGS. 5 and 5A. Exchangeable sodium content (m. e.) of soils of Gujranwala district in relation to the yield of rice



FIGS. 6 and 6A. Exchangeable sodium content (m. e.) of soils of Sheikhupura district in relation to the yield of rice

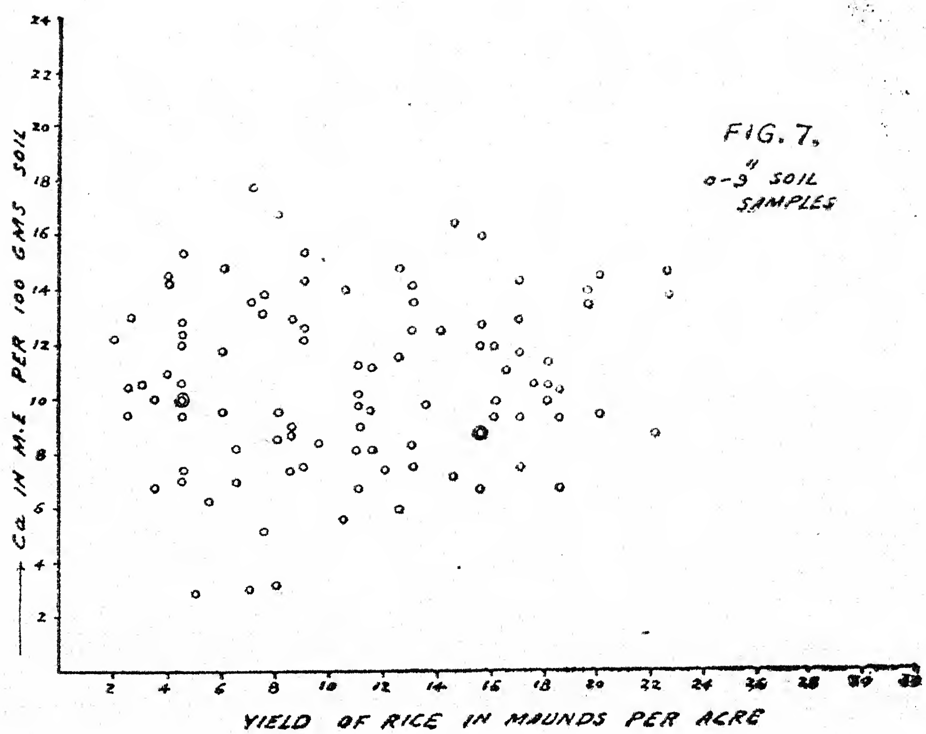
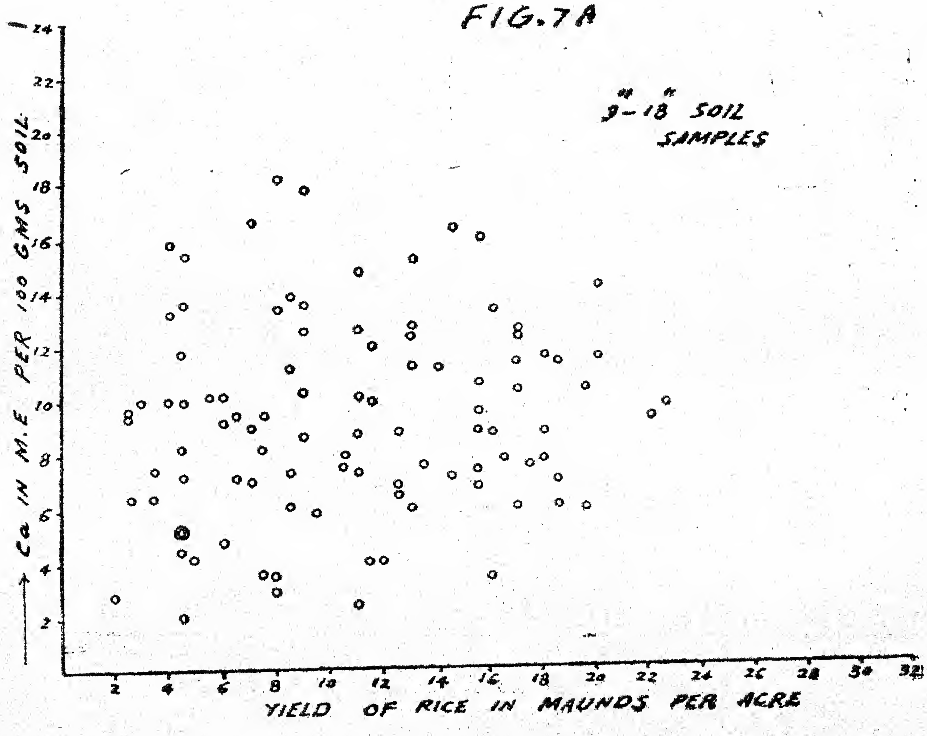
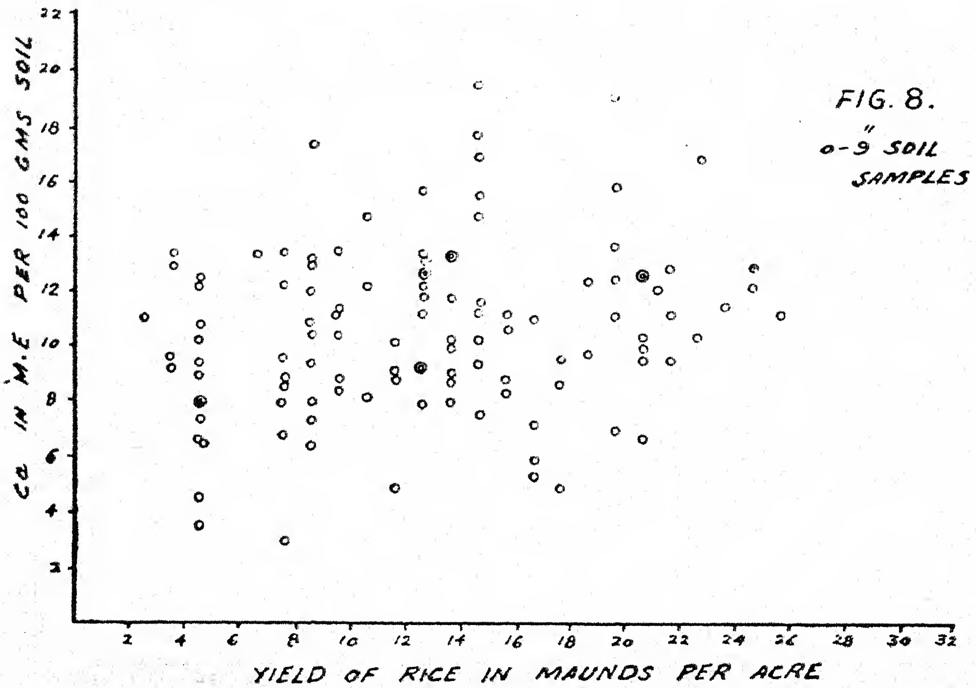
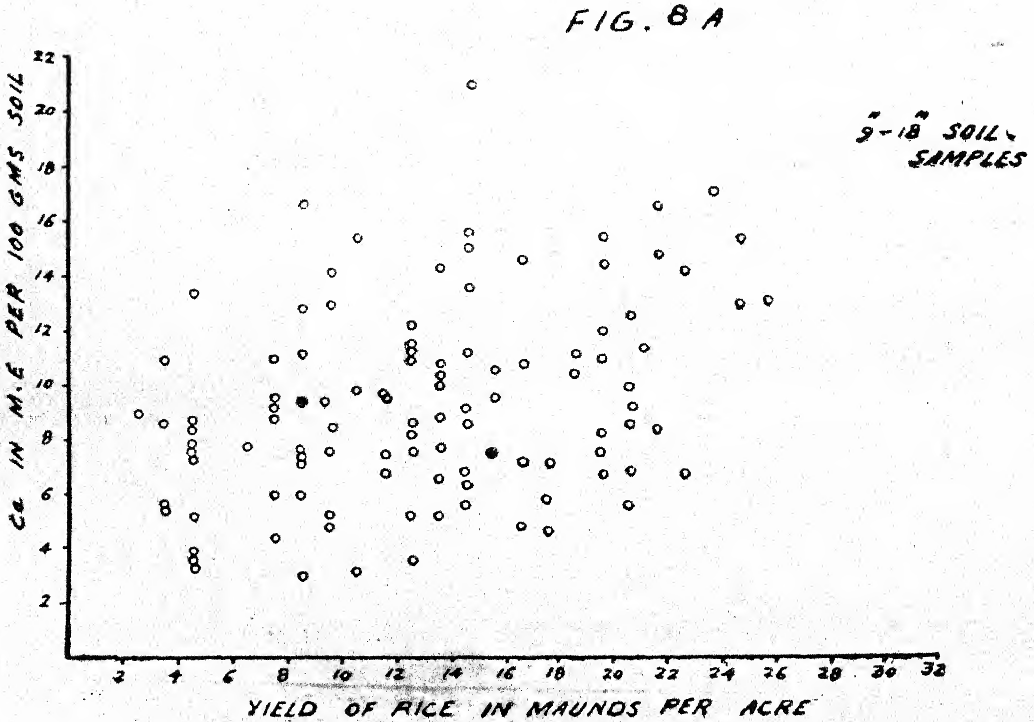


FIG. 7A

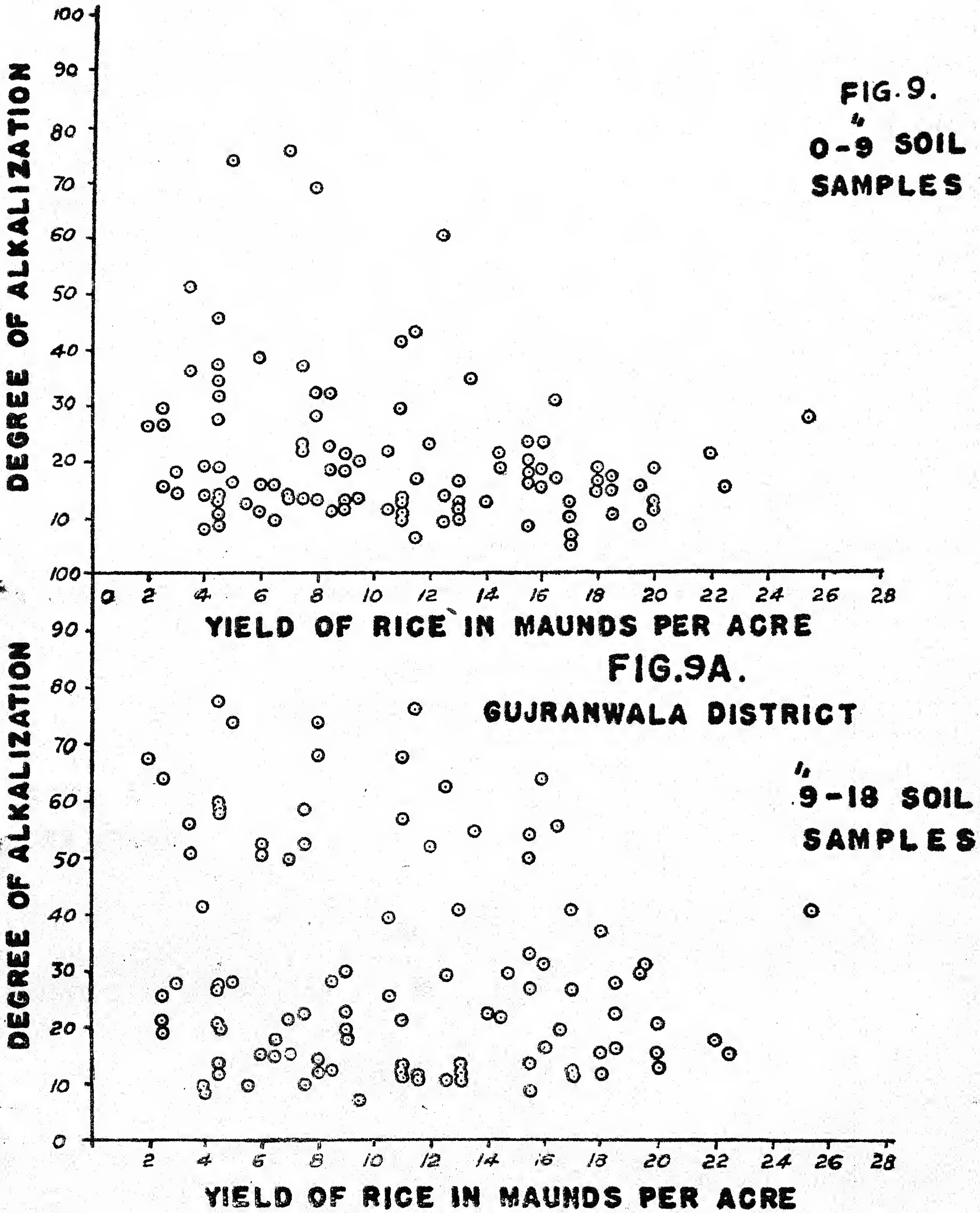


FIGS. 7 and 7A. Exchangeable calcium content of soils of Gujranwala district in relation to the yield of rice

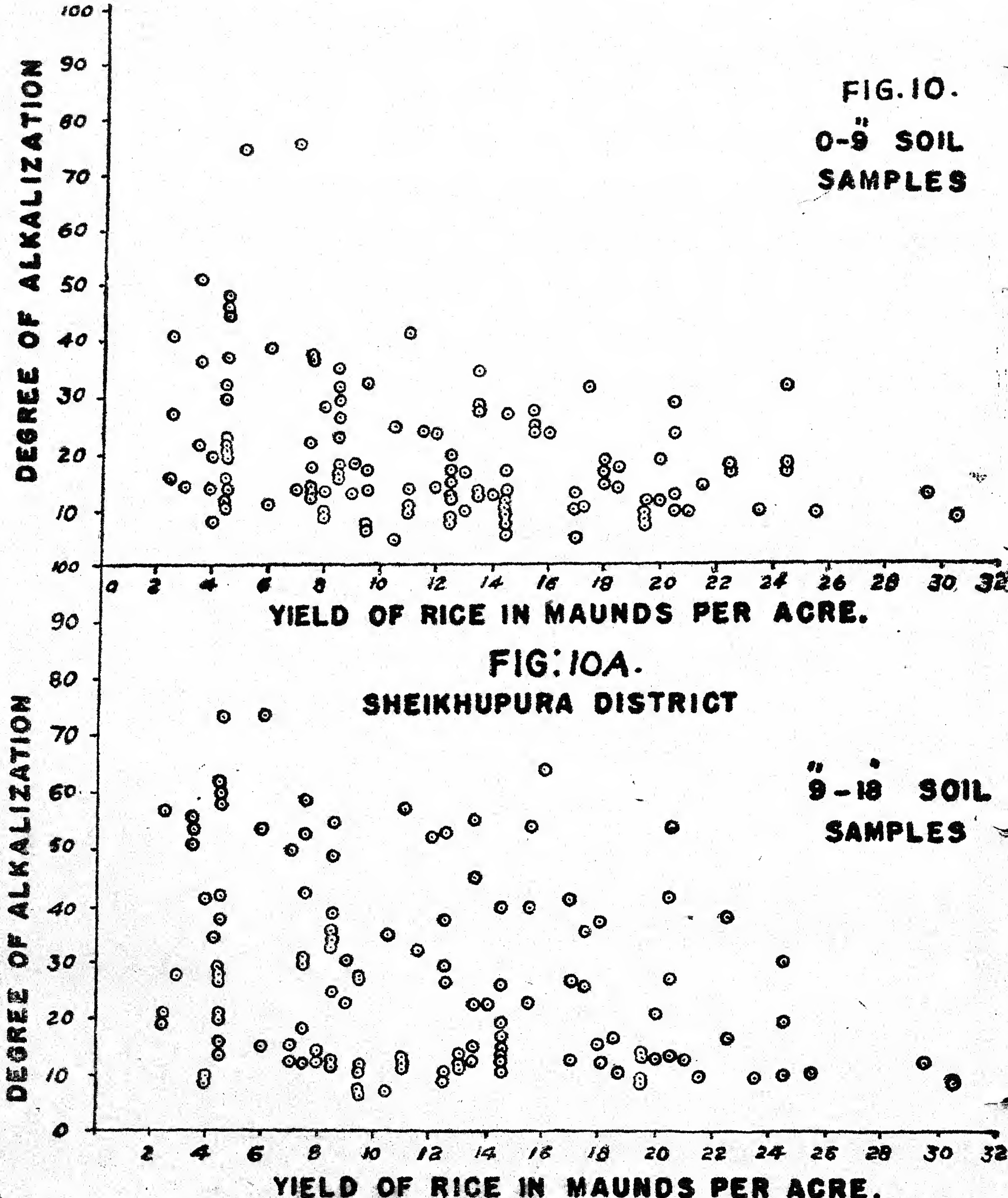




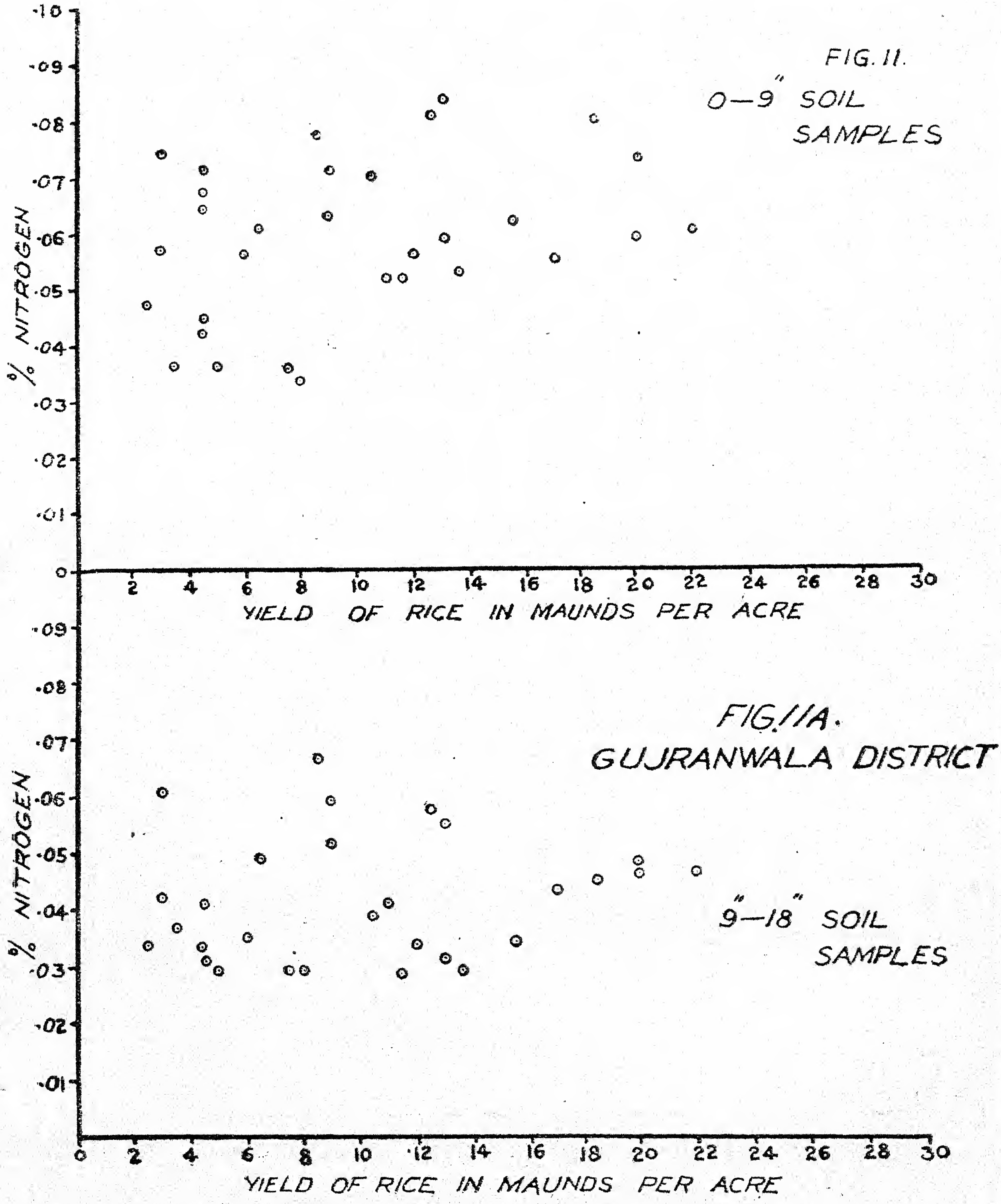
FIGS. 8 and 8A. Exchangeable calcium content of soils of Sheikhupura district in relation to the yield of rice



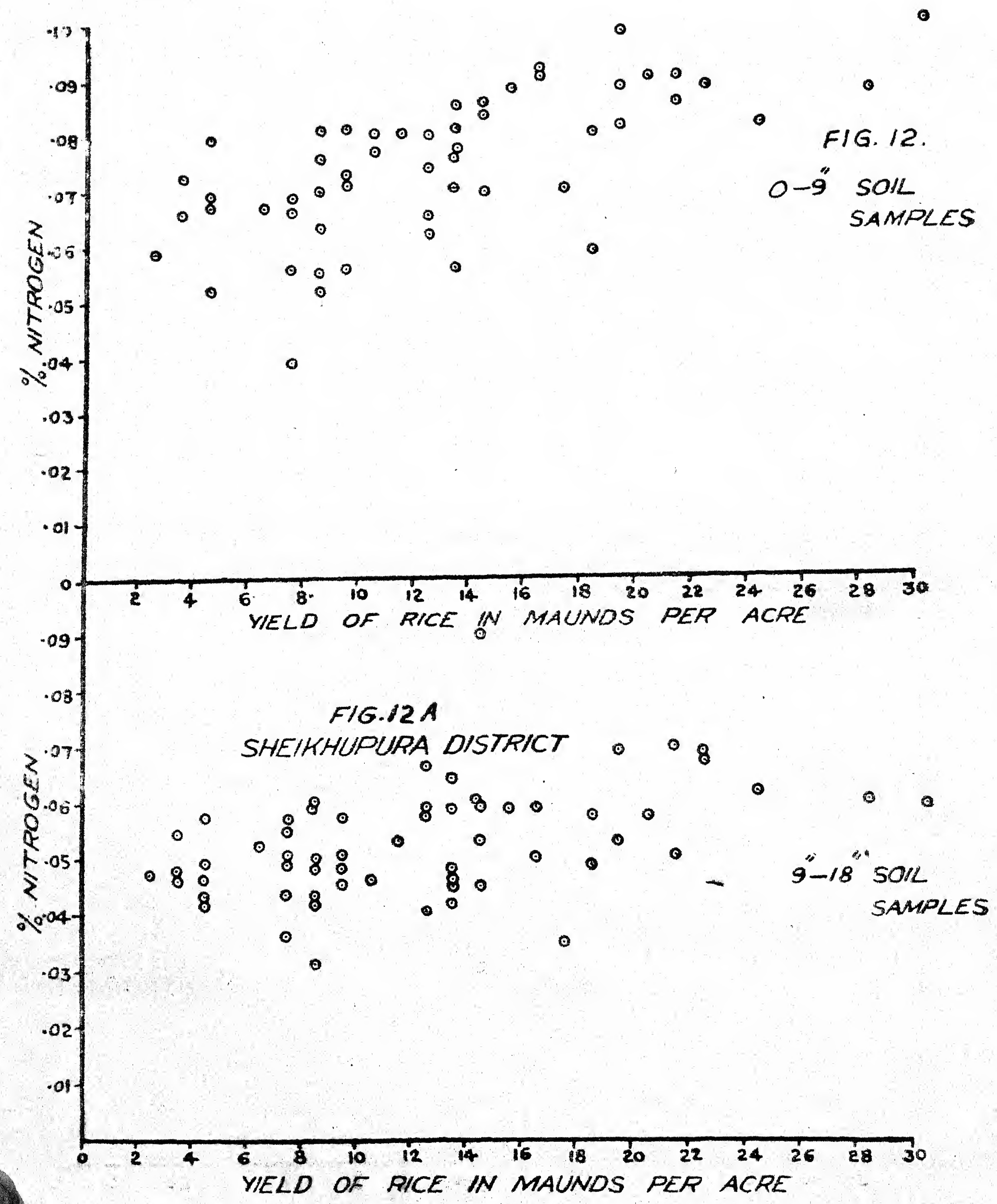
FIGS. 9 and 9A. Degree of alkalization of soils of Gujranwala district in relation to the yield of rice



FIGS. 10 and 10A. Degree of alkalization of soils of Sheikhupura district in relation to the yield of rice



FIGS. 11 and 11A. Percentage of nitrogen content of soils of Gujranwala district in relation to the yield of rice



FIGS. 12 and 12A. Percentage of nitrogen content of soils of Sheikhupura district in relation to the yield of rice

FIG. 13.

0-9" SOIL SAMPLES

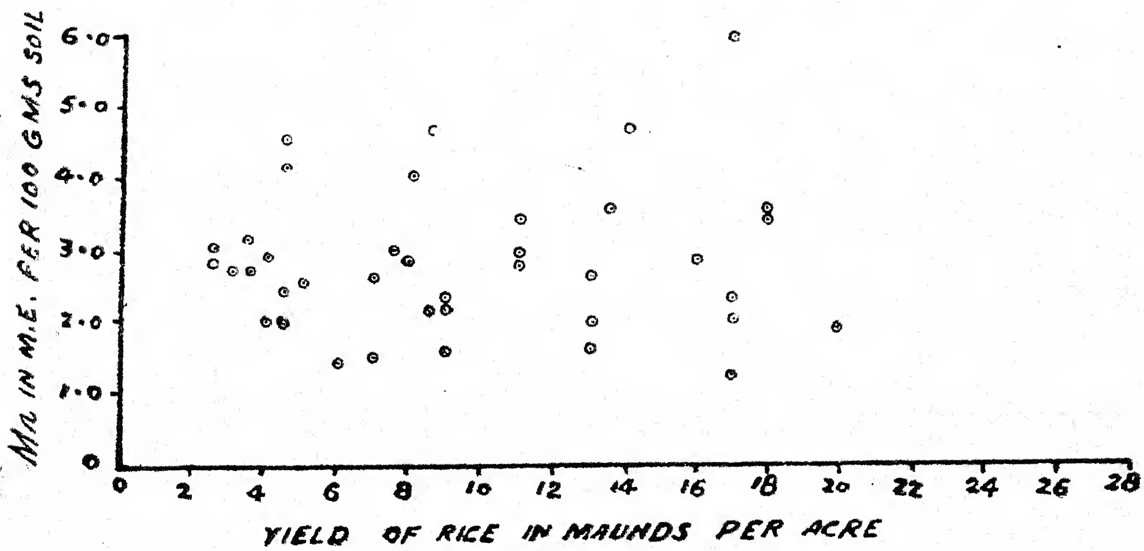
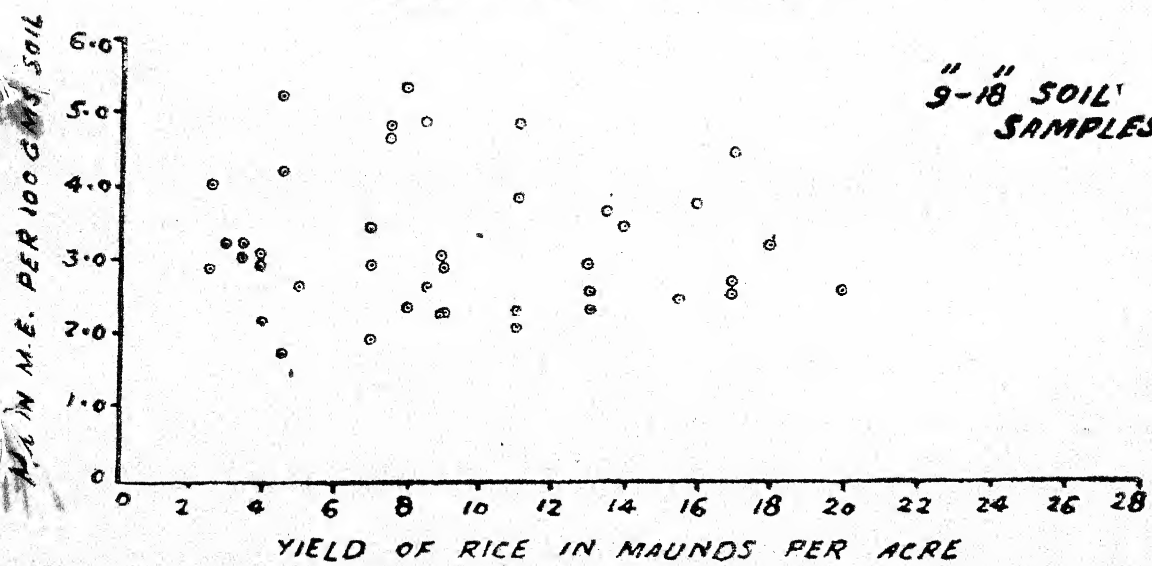


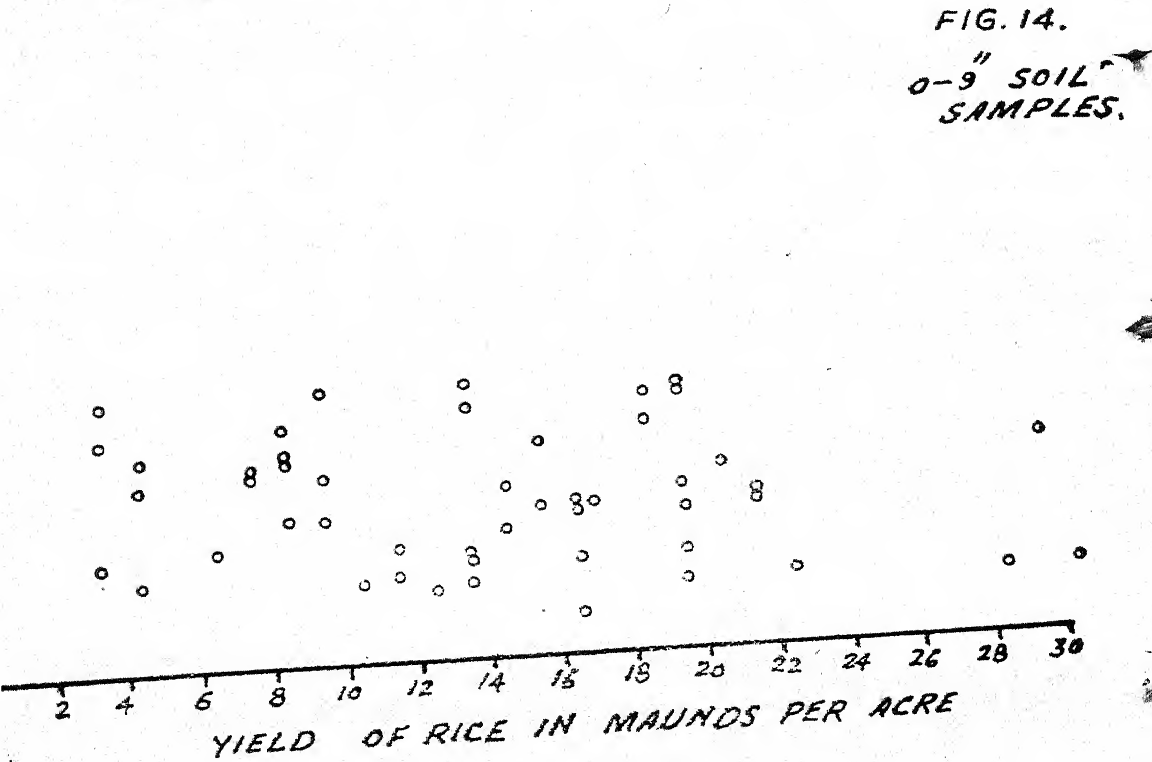
FIG. 13A

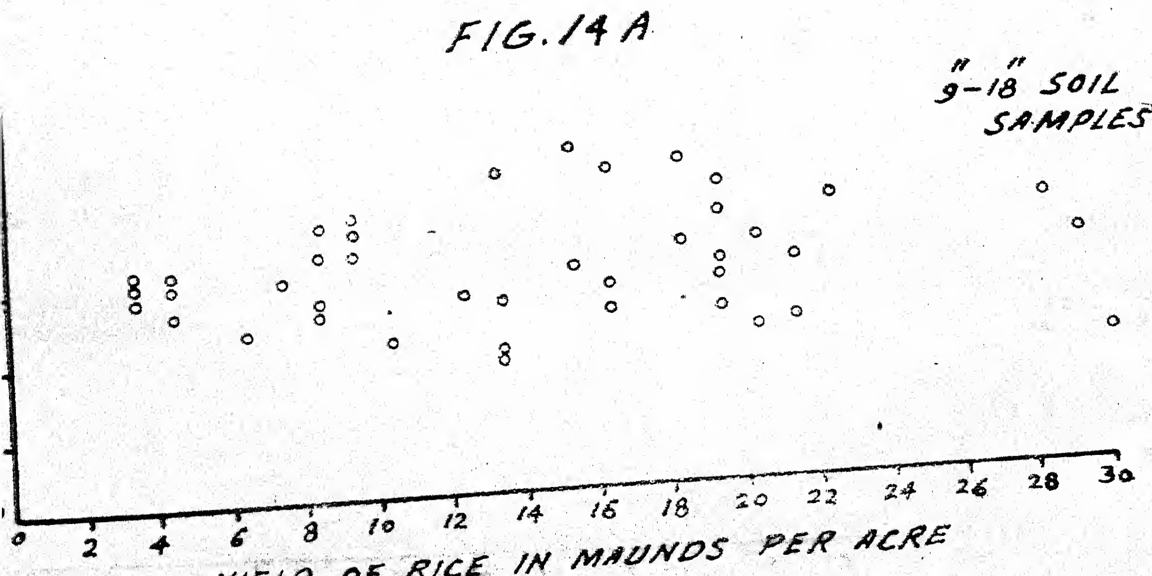
GUJRANWALA DISTRICT

9"-18" SOIL SAMPLES

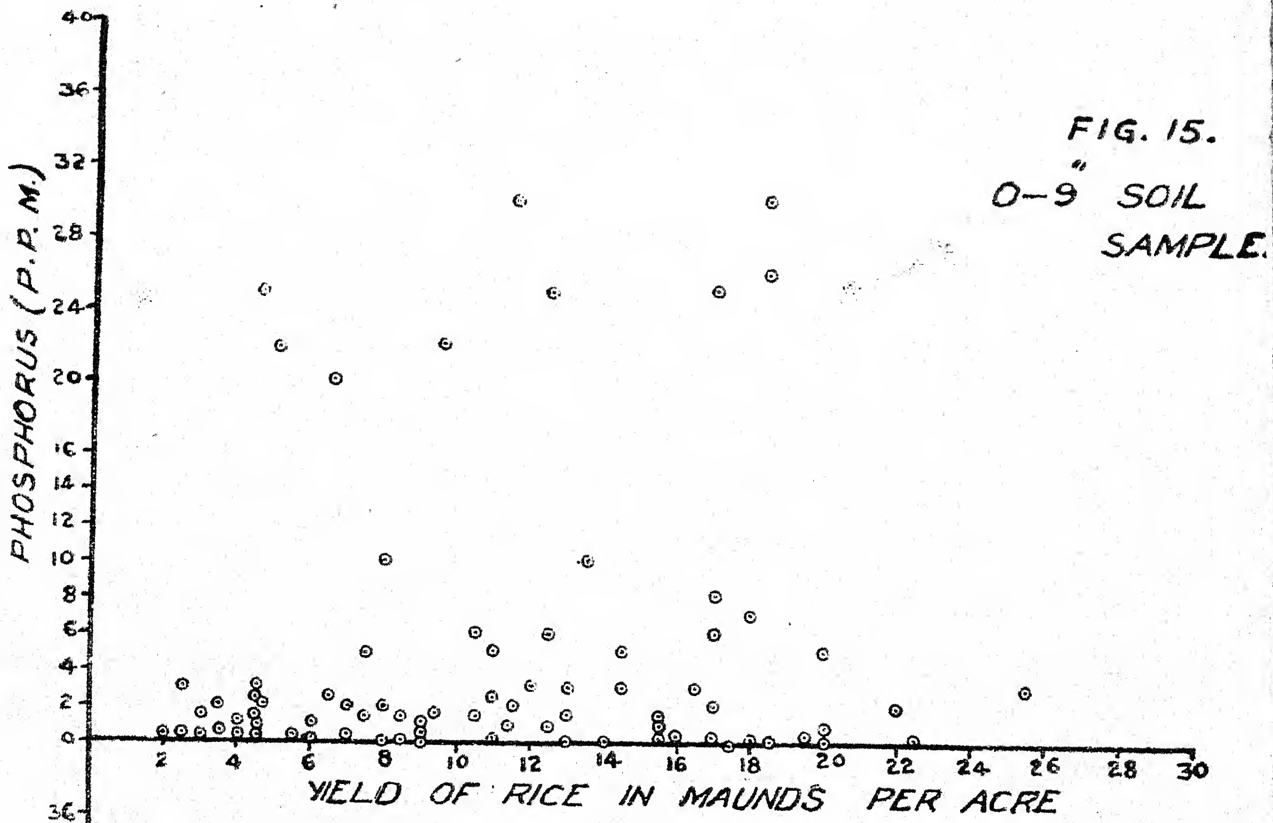


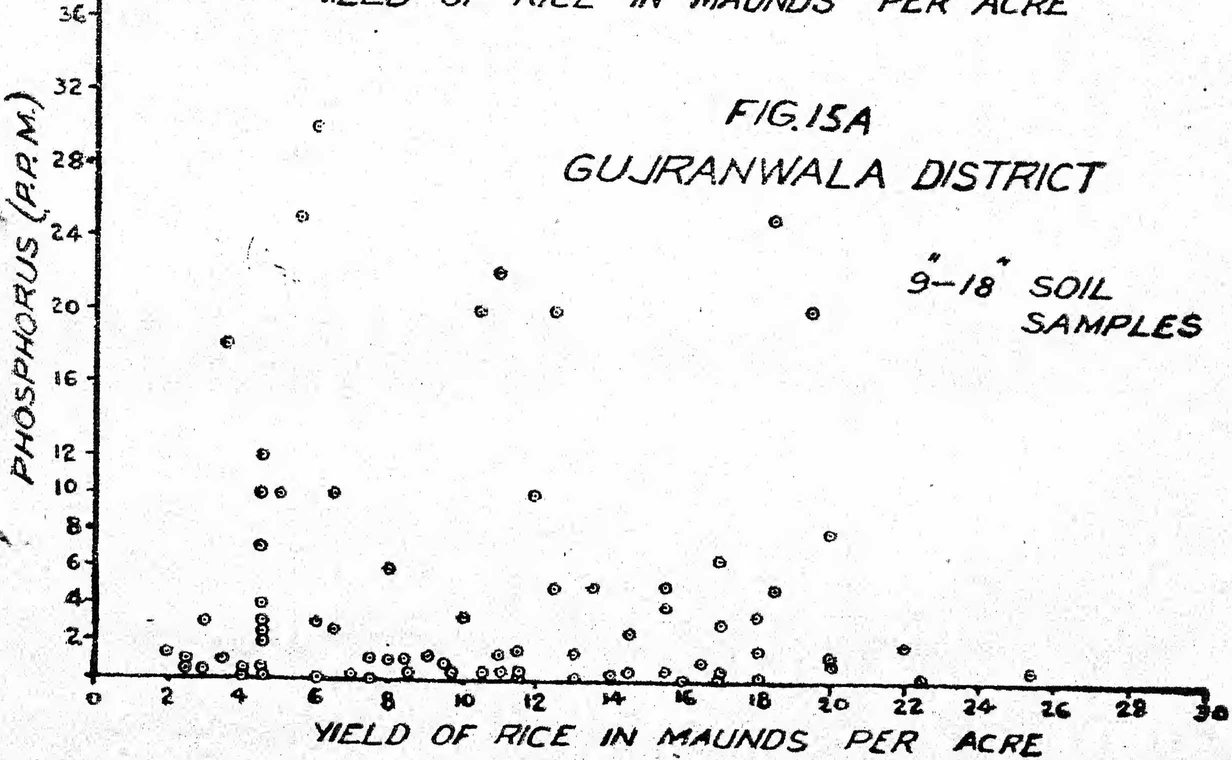
FIGS. 13 and 13A. Manganese content of soils of Gujranwala district in relation to the yield of rice



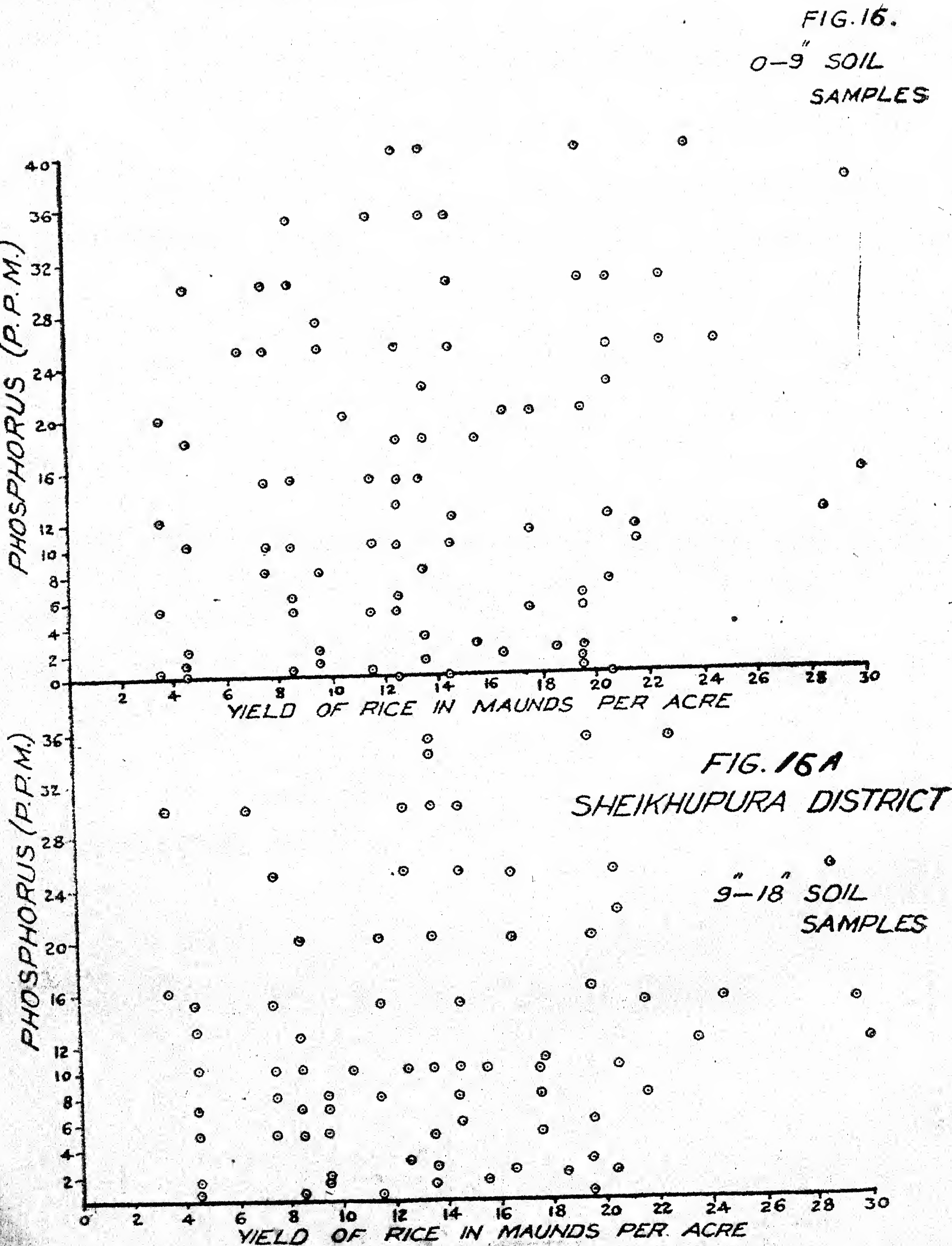


FIGS. 14 and 14A. Manganese content of soils of Sheikhupura district in relation to the yield of rice





FIGS. 15 and 15A. Available phosphate content (p.p.m.) of soils of Gujranwala district in relation to the yield of rice



FIGS. 16 and 16A. Available phosphate content (p.p.m.) of soils of Sheikhupura district in relation to the yield of rice

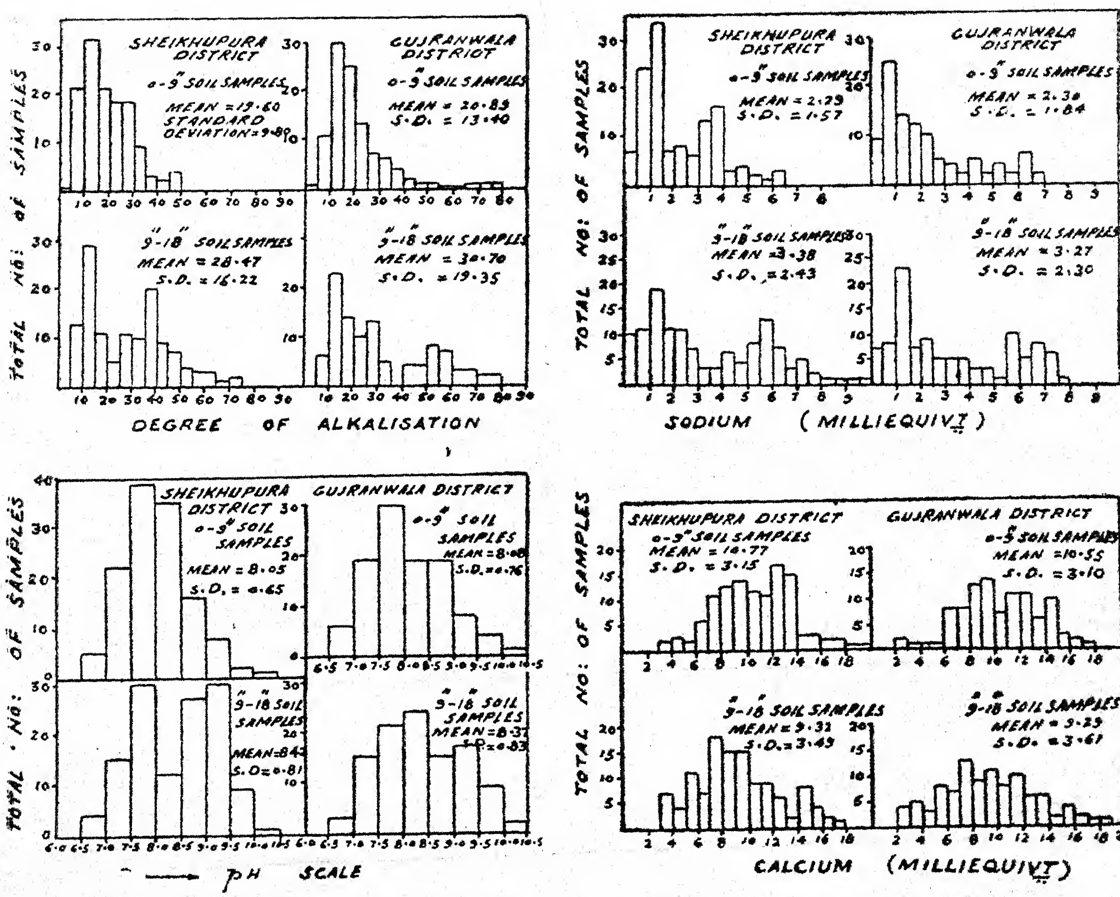


FIG. 17. Distribution of certain soils characteristics in rice areas of Gujranwala and Sheikhupura districts

Statistical treatments of analytical results

An examination of the Figs. 1-17 and 1A-16A brings out diagrammatically the sort of relationship between the yield figures and the main soil characteristics and seems to indicate sufficient scope for further elucidation on statistical basis particularly of the following :

(i) Soluble salts (above 0·2 per cent) for soils of Sheikhupura district only
(ii) *p*H
(iii) Exchangeable sodium and calcium base contents
(iv) Degree of alkalization
(v) Nitrogen content
(vi) Manganese content

Further, histrograms of (ii), (iii) and (iv) soil characteristics are presented in Fig. 17. The distribution of the results of the exchangeable sodium content and degree of alkalization are very skew indicating that the soils with low contents of those characteristics are more frequent than those of high contents.

The statistical analyses resulted in a number of correlations between the above-mentioned soil characteristics and the rice yield figures, which, for soils of Gujranwala and Sheikhupura districts, are given in Tables I and II respectively. Tables III and IV show some of the statistical constants relating to the multiple regression of the yield figures with certain characteristics of soils of those two districts respectively. The partial and multiple correlations of yield figures with *p*H and nitrogen content of soils of the two districts are given in Tables V and VI respectively.

Table I

Correlation of yield of rice with certain soil characteristics of the first and second 9 inches soil samples of Gujranwala district

Soil characteristics	No. of observations	Correlation of soil characteristic between 1st and 2nd 9 in.	Total 1st 9 in.	Correlation 2nd 9 in.	Multiple correlation
Degree of alkalization	105	0·6419†	—0·2175*	—0·1662	0·2202
*p*H	106	0·8084†	—0·3151†	—0·2472*	0·3151†
Sodium	104	0·7479†	—0·2015*	—0·1308	0·2038
Calcium	100	0·4616†	0·911	0·1046	0·1150
Nitrogen	21	..	..	0·2831[1]	..

[1] Correlation with the average value in the 1st and 2nd 9 in. soil samples
*Indicates significance at 5 per cent level
†Indicates significance at 1 per cent level

Table II

Correlation of yield of rice with certain soil characteristics of the first and second 9 inches soil samples of Sheikhupura district

Soil characteristics	No. of observations	Correlation of soil characteristic between 1st and 2nd 9 in.	Total 1st 9 in.	Correlation 2nd 9 in.	Multiple correlation
Degree of alkalization	128	0·6934	—0·2180*	—0·3151†	0·3153
*p*H	128	0·8460	—0·1380	—0·1638	0·1638
Sodium	128	0·6251	—0·1714	—0·2874†	0·2876†
Calcium	128	0·6088	0·2693†	0·3415†	0·3500†
Soluble salts	[illegible]	Not calculated	—0·0459	—0·0004	..
Nitrogen	66	..	..	0·6884[1] †	..

[1] Correlation with the average value in the 1st and 2nd 9 in. of soil
*Indicates significance at 5 per cent level
†Indicates significance at 1 per cent level

TABLE III

Some statistical constants connected with the multiple regression of yield of rice and certain characteristics of soils of Gujranwala district

No. of observation=98

Statistical constant	Yield	Degree of alkalization	pH	Sodium	Calcium
Mean	10·54	21·01	8·11	2·36	10·57
Standard error of mean	5·37	13·80	0·766	1·88	3·11
Correlation with yield (y)	..	0·2687	—0·3390	—0·2419	0·0830
Correlation with D.A.	..	..	0·5781	0·8191	—0·5038
Correlation with pH	..	..	..	0·7342	—0·1120
Correlation with Na	..	..	..	..	—0·2101
Multiple correlation of yield with D.A.	0·3682	..	..	..	..
Partial regression coefficient of yield	..	—0·1138	—2·5279	0·7190	—0·0894
Partial regression coefficient	..	—0·2921	—0·3602	0·2510	—0·0518
"t" for significance of partial regression coefficient	..	1·40	2·53**	1·17	0·42

N.B.—(1) The values of D.A., pH, Na and Ca taken are those in the 1st 9 in. of soil
(2) **denotes significance on 1 per cent level

TABLE IV

Some statistical constants connected with the multiple regression of yield of rice and certain characteristics of soils of Sheikhupura district

No. of observations=62

Statistical constant	Yield	Degree of alkalization	pH	Sodium	Calcium
Mean	12·03	26·05	3·23	10·19	641·58
Standard error of mean	5·66	10·63	1·87	3·12	113·06
Correlation with yield (Y)	..	—0·4425	—0·3067	+0·3909	+0·6788
Correlation with pH	..	..	+0·8049	—0·4926	—0·4276
Correlation with Na	..	..	..	..	+0·4064
Multiple correlation of yield with D.A., pH, Na and Ca.	0·6992	..	..	..	..
Partial regression coefficient of yield	..	—0·1614	+0·4780	+0·0460	+0·0290
Partial standard regression coefficient	..	—0·3027	+0·1579	+0·0253	+0·5796
"t" for significance of partial regression coefficient	..	1·47	0·85	0·20	5·36

N.B.—(1) The values of D.A., pH, Na and Ca are the average values of the 1st and 2nd 9 in. of soil
(2) **denotes significance on 1 per cent level

TABLE V

Partial and multiple correlation of yield of rice (Y) with pH and nitrogen, Gujranwala district

No. of observations=31

Statistical constant	Yield	*p*H	Nitrogen
Mean	9·81	8·47	500·61
Standard error of mean	5·55	0·866	111·62
Correlation with yield	..	—0·5511	0·2831
Correlation with *p*H	..	..	—0·6979
Partial correlation with yield	..	—0·5147	—0·1699
Multiple correlation of yield with *p*H and N	0·5690	..	..

N.B.—The values of *p*H and N are taken as the average value in the 1st and 2nd 9 in. soil samples

TABLE VI

Partial and multiple correlation of yield of rice (Y) with pH and nitrogen, Sheikhupura district

No. of observations=66

Statistical constant	Yield	*p*H	Nitrogen
Mean	13·03	8·26	649·26
Standard error of mean	6·78	0·681	114·26
Correlation with yield	..	—0·2629	+0·6884
Correlation with *p*H	..	..	—0·3459
Partial correlation with yield	..	—0·0364	+0·6600
Multiple correlation of yield with *p*H and N	0·6889	..	..

N.B.—(1) The values of *p*H and N are taken as the average value in the 1st and 2nd 9 in. soil samples
(2) The units in which the mean values are expressed are as below :
Y = Yield of Md./Acre
*p*H = already explained under Table III
N = Percentage

From the various statistical relations given in the tables it is apparent that any soil characteristic of the top nine inches sample is, generally speaking, positively correlated with the same characteristic of the second nine inches samples, i.e. a high content in the top samples means generally a high content in the second nine inches samples and vice versa.

THE EFFECT OF THE VARIOUS SOIL CHARACTERISTICS ON THE YIELD OF RICE

(*a*) *Soluble salt content of soils.* A comparison of the Figs. 1, 1A, 2 and 2A, in which the results of the soluble salt content of soils of the two districts are diagrammatically represented against the yield figures, shows that there are comparatively larger number of sites having soluble salt content higher than 0·2 per cent in Sheikhupura than in Gujranwala district. It may be of interest to further investigate the causes of this difference in the saline content of soils of the two districts. There is no definite statistical relationship between the yield of rice and soluble salt content of soils below 0·2 per cent. The statistical correlation between soils of Sheikhupura district having salt

content higher than 0·2 per cent and yield figures also works out to be insignificant as shown in Table II.

(*b*) p*H values of soils.* Figs. 3, 3A, 4 and 4A represent the relationship of yield figures and the *p*H of soils. The various statistical correlations are given in the tables. For soils of Gujranwala district, it is brought out that—

(i) The *p*H of the top and second nine inches soil samples bear a significant correlation with yield figures.

(ii) The partial regression coefficient is also very significant.

(iii) The total correlation coefficient for figures of *p*H and yield, i.e. 0·339 is not significantly different from the multiple correlation coefficient (0·364).

(iv) There exists a significant correlation between the *p*H of soils and the yield of rice, i.e. the greater the *p*H the less the yield and vice versa. This does not, however, mean that other soil characteristics have no effect on yield but they are so distributed in relation to *p*H that their effect is not markedly apparent.

(v) The regression formula for the yield figures (Y) in maunds per acre and the average value of *p*H of total depth of soil examined, i.e. 18 in., for Gujranwala district is:

$$Y = 39{\cdot}72 - 3{\cdot}53\ p\mathrm{H}.$$

It is rather interesting that there does not exist any significant correlation between *p*H and yield figures for soils of Sheikhupura district. The partial correlation of *p*H and yield figures for that district is also insignificant.

It seems, therefore, that *p*H of soils is one of the determining factors for the yield of rice as far as the soils of Gujranwala district only are concerned but not for those of Sheikhupura district.

(*c*) *Exchangeable base content of soils.* The contents of the main exchangeable bases, i.e. sodium, potassium, calcium and magnesium were determined for all soil samples. The results of the exchangeable sodium and calcium contents of soils, which only seemed to yield significant statistical relationships, have been plotted against respective yield of rice figures in Figs. 5-8 and 5A-8A for the top and second nine inches soil samples respectively of the two districts.

The main conclusions regarding the effect of exchangeable base content of soils and the yield figures are:

(i) The correlation between the yield figures and the sodium content of the top nine inches soil samples of Gujranwala district is significant but that with the calcium content of those soils is insignificant.

(ii) The correlations of the calcium content of the top and 2nd nine inches soil samples of Sheikhupura district with respect to yield figures are significant and so is the correlation of the sodium content of the second nine inches soils of that district.

(iii) The multiple correlations of sodium and calcium are not significant for soils of the two districts.

(*d*) *Degree of alkalization.* Degree of alkalization is defined as the ratio of the amount of exchangeable monovalent ions (Na + K) in the soil to maximum amount of monovalent ions the soil is capable of binding [Puri, 1933]. It appears that, where exchangeable sodium is the limiting factor, the yield of rice shows a significant correlation with this value also.

The results of the degree of alkalization for the top and second nine inches soils of the two districts are plotted in relation to the yield figures in Figs. 9, 9A, 10 and 10A and the statistical correlations are presented in the various tables. It is seen that whereas the statistical correlations between the yield figures and the degree of alkalization of both the top and second nine inches soils are significant for samples of Sheikhupura district those for soils of Gujranwala district are only significant for the top nine inches and not for the 2nd nine inches soil samples. This difference in the behaviour of the soils of the two districts is rather interesting.

(*e*) *Total nitrogen content of soils.* The results of the percentage nitrogen content of soils in relation to the yield figures are plotted in Figs. 11, 11A, 12 and 12A for the top and second nine inches soil samples respectively of the two districts. The statistical correlations have been worked out on the basis of the average nitrogen content for the whole 18 inches depth of soil and given in

the tables. There were 66 and 36 observations for Sheikhupura and Gujranwala districts respectively. As shown in Table II, the multiple correlation figures are also highly significant. The corresponding correlation figures for soils of Gujranwala districts are, however, not so significant. Unlike the behaviour of soils of Gujranwala district, therefore, it is the nitrogen content of soils which determines the yield of rice in Sheikhupura district. It does not mean, however, that other soil characteristics have no influence on the yield of rice but they are so distributed in relation to the nitrogen content that their effect does not seem to be as marked as that of nitrogen content of soil. The regression formula for the yield figures (Y) and the nitrogen content of soil (N) is as follows :

$$Y = 0{\cdot}0408\ N - 13{\cdot}49$$

(*f*) *Manganese content of soils.* The results of the manganese content of soils in relation to the yield figures are plotted in Figs. 13, 14, 13A and 14A for the top and second nine inches soil samples of the two districts. The statistical correlations are given below :

Name of district	*Top 9 in. soils*	*Second 9 in. soils*
Gujranwala	+0·0305	−0·0702
Sheikhupura	−0·2106	+0·0594

The correlations are not significant which implies that, as far as the yield of rice is concerned the manganese content of soils is not a determining factor for soils of any of the two districts. A very significant negative correlation between the yield of wheat and this soil characteristic was found for wheat soils reported in the previous publication [1941] relating to wheat soils.

(*g*) *Available phosphate content of soils.* The results of the available phosphate content of soils in relation to the yield of rice are graphically represented in Figs. 15, 15A, 16 and 16A. A comparison of the figures for the two districts brings out one very interesting difference. The soils of Gujranwala district have a comparatively much lower available phosphate content than those of Sheikhupura district. It may be of interest to investigate further the cause of this difference in the available phosphate content of soils of those two districts. Also on the whole, the available phosphate content of soils, under present investigation, are lower than those of wheat soils reported in the previous publication.

As is apparent from the diagrams, the available phosphate contents of soils do not seem to bear any relation to the yield of rice figures and hence no attempt has been made to work out the relationship statistically. As far as this soil characteristic is concerned there again exists a very conspicuous difference in respect to its effect on the rice and wheat yields. In the latter, a very significant positive correlation was found to exist between the available phosphate content of soils and the yield of wheat.

(*h*) *Boron content of soils.* The results of the boron content of soils do not seem to indicate any relation to the yield of rice. No statistical correlation was, therefore, obtained in this case.

Conclusion

The statistical interpretation of the effect of the various characteristics on the yield of rice for the top (A) and the second (B) nine inches soils samples of the two districts are summarized in tabular form below :

Soil characteristic	Soils of Gujranwala district	Soils of Sheikhupura district
pH . .	Significant for both A and B	Not significant
Na . .	Significant for A only	Significant for B only
Ca . .	Insignificant	Significant for both A and B
D.A. . .	Significant for A only	Significant for both A and B
N . . .	Insignificant	Highly significant

Summary

The top and second nine inches soil samples from rice areas in Gujranwala and Sheikhupura districts of the Punjab have been analysed and the results of the analyses employed for determining the statistical correlations with the figures for yield of rice at those sites. It is brought out that the soil characteristics which manifest significant correlations with yield are *p*H, exchangeable sodium and degree of alkalinity for soils of Gujranwala district and exchangeable calcium and sodium, degree of alkalinity and nitrogen for soils of Sheikhupura districts.

The manganese and available phosphate contents of soils do not seem to affect the yield of rice which is at variance to what has been reported for wheat soils of the Punjab in the previous publication.

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THE WILT DISEASE OF PIGEON PEA [*CAJANUS CAJAN* (L.) MILLSP.] WITH SPECIAL REFERENCE TO THE DISTRIBUTION OF THE CAUSAL ORGANISM IN THE HOST TISSUE *

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I. Introduction

From the time when the wilt disease of pigeon pea (*Cajanus cajan*) was first investigated by Butler, it has been known that the causal fungus *Fusarium udum* Butler forms frequently on the surface of the bark of diseased plants masses of salmon-pink spores which may be either macro- or micro-conidia. The author, while studying the disease, found that spore masses could often be observed in the branches of the diseased plants to a height of several feet. It was also observed that the disease may at times become manifest through the wilting of individual branches. The spores which are found mainly in the axes of branches, germinate readily under favourable conditions.

*This investigation was carried out in partial fulfilment of the requirements for the Diploma of Associateship of the Imperial Agricultural Research Institute, New Delhi

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It is questionable to what section of *Fusarium* the causal organism belongs. It was for a time regarded as a race of *Fusarium vasinfectum* Atk., which would place it in the section Elegans. Padwick [1940], however, showed that in several respects *F. udum* differed sharply from *F. vasinfectum* and considered it a good species. Wollenweber [1938] described as *F. lateritium* var. *uncinatum*, a fungus which Padwick [1940] showed to be identical with *F. udum*. The placing of the fungus in *F. lateritium*, to which it has much resemblance, would bring it within the section Lateritium. Section Elegans contains most of the wilt causing organisms which invade the plants through the roots. Section Lateritium has fungi which have the habit of establishing themselves on the surface of tissue of above ground parts of plants.

The presence of large spore masses on the bark of affected plants, and the close resemblance of *Fusarium udum* to species of the section Lateritium, raises the question whether such spores, spread either by wind or, which is more likely, by rain-, flood-, or irrigation-water, establish themselves on the surface of the tissue and then invade it, giving rise to the observed phenomenon of wilting in individual branches. The woody nature of the host plant does not lend itself to a direct study of the question. However, an indirect approach was possible. If the spore masses appear on the surface of the tissue at points above the places at which the fungus is found within the vessels, it is likely that infection has taken place from the outside. If on the other hand, infection of the vessels is found always in advance of the appearance of the spore masses externally, it must be presumed that the latter is a post-mortem phenomenon, the fungus having advanced through the vessels, then destroyed the cortex, and sporulated externally. An examination was therefore made of a large number of branches in plants in various stages of the disease to compare the internal spread of the fungus with its external production of spores.

II. Internal and external distribution of the fungus

From an infested field, plants in various stages of the disease were collected and were classified as follows:

(1) Plants which have long died, showing the superficial pink colorations to some height, but bearing no pods and seeds; (2) plants which have long died, showing the superficial pink colorations to some height, but bearing pods and seeds; (3) plants which have freshly wilted, having one or more branches affected; (4) normal, healthy plants. These groups of plants were named A, B, C and N respectively. Out of these four categories of plants, four plants of group A, four of B, five of C and five of N were selected for this experiment. Isolations, starting from the ground level, were taken at every sixth inch in height, including the various primary branches. In the plants which had freshly wilted, at every height two corresponding isolations were taken from diametrically opposite points on the stem, one line of isolation being restricted to that side of the stem showing black streaks either on the bark or on the wood. This was done to ascertain if the fungus was specially located in those regions of the stem wherefrom the branches had wilted.

To determine the internal spread of the fungus, marks were made at every sixth inch of the plants, and from every such point, starting from the ground level, wood of $\frac{3}{4}$ in. in length was cut off. Then the bark was completely removed with a pen-knife and the wood was longitudinally split into five sticks. These sticks were then placed in one per cent silver nitrate solution for one minute and washed in two per cent sterilized solution of sodium chloride for two minutes and were finally placed in five tube slants containing potato dextrose agar. After a fortnight when the fungus grew in culture, it was examined under the microscope and note was made when *F. udum* had grown out of the sticks.

To determine the external vertical distribution of the spores, scrapings from the surface of plants belonging to group A, B and C were taken at various heights. The slides so prepared were examined under the microscope to see if any spore of *F. udum* was present.

The results of the above experiment are indicated in Tables I, II and III.

TABLE I

Isolations from plants of group A

(Plants long dead, without pods and seeds)

Plants	Branches	Total height in feet	External distribution in feet	Internal distribution in feet
A_1	Main stem	9·0	6·4	7·5
	b_1 (branch 1)	7·2	4·8	7·0
	b_2	7·0	4·6	6·5
	b_3	8·0	5·1	7·5
A_2	Main	7·5	4·5	6·5
	b_1	7·0	2·2	5·0
	b_2	7·2	4·2	6·5
	b_3	7·0	1·3	5·0
A_3	Main	8·7	4·0	6·5
	b_1	8·7	3·8	7·0
	b_2	7·4	1·7	4·5
	b_3	8·3	4·0	5·5
	b_4	6·6	5·0	6·5 (topmost)
	b_5	5·5	4·2	5·5 (topmost)
	b_6	8·2	6·0	8·0 (topmost)
A_1	Main	7·7	5·9	6·5
	b_1	8·7	6·0	8·0
	b_2	8·1	5·5	6·0
	b_3	8·5	5·5	7·5

TABLE II

Isolations from plants of group B

(Plants long dead, with pods and seeds)

Plants	Branches	Total height in feet	External distribution in feet	Internal distribution in feet
B_1	Main	10·0	4·1	10·0 (topmost)
	b_1	[illegible]	4·7	7·0
	b_2	6·2	2·5	4·5
	b_3	8·3	3·0	4·0
	b_4	9·0	3·3	7·0
	b_5	6·3	2·5	3·5
B_2	Main	8·0	0·5	2·5
	b_1	7·2	*nil*	1·0
	b_2	5·3	*nil*	*nil*
B_3	Main	9·5	1·0	3·0
	b_1	9·1	*nil*	1·0
	b_2	8·0	*nil*	*nil*
B_4	Main	9·0	3·3	9·0 (topmost)
	b_1	8·5	1·9	8·5 (topmost)
	b_2	8·2	2·08	6·5
	b_3	7·0	2·2	6·0
	b_4	7·7	4·5	7·0

TABLE III

Isolations from plants of group C

(Plants freshly wilted)

Plants	Branches	Total height in feet	External distribution in feet	Internal distribution on the line of wilted branches	Internal distribution on the line diametrically opposite to that of wilted branches
C_1	Main	9·0	*nil*	1·0	*nil*
	b_1	6·5	,,	*nil*	X
	b_2	8·5	,,	,,	X
	b_2	7·5	,,	,,	X
	b_4	8·0	,,	,,	X
C_2	Main	9·0	*nil*	1·5	*nil*
	b_1	9·0	,,	0·5	X
	b_2	8·5	,,	*nil*	X
	b_3	7·0	,,	2·0	X
C_3	Main	9·5	*nil*	0·5	*nil*
	b_1	8·0	,,	1·0	X
	b_2	6·5	,,	*nil*	X
	b_3	8·5	,,	,,	X
C_4	Main	9·0	*nil*	0·5	*nil*
	b_1	8·5	,,	*nil*	X
	b_2	8·5	,,	2·5	X
	b_3	7·0	,,	*nil*	X
C_5	Main	9·5	*nil*	0·5	*nil*
	b_1	9·0	,,	2·5	X
	b_2	8·0	,,	*nil*	X
	b_3	8·5	,,	,,	X

The results in Tables I and II show that the fungus, in infected branches both externally and internally, is always traceable without any discontinuity from the base upwards, and the internal vertical spread of the fungus is always higher than that of the external. Secondly in some branches of some plants belonging to the group A, as well as to group B, the fungus reaches internally the top showing the possibility of its further spread into the pods and the seeds.

The results in Table III show that the fungus is always present at different heights of isolation without any discontinuity and this can only be located on the side of the stem having blackened areas. On the other hand, it cannot be traced in the diametrically opposite side of the stems which have not been so blackened, and where the branches do not show any sign of wilting. The fungus is always traceable right from the base upwards to a height 2-2½ feet.

The isolation experiments on the normal, healthy plants show the absence of fungus both externally and internally.

The possibility of seed transmission

Many *Fusaria* causing wilt diseases in various plants are known to be seed-borne. Orton [1931] lists about 15 such species carried on about 16 different host plants. Since the publication of the paper by Orton [1931], various other cases about the seed-borne nature of *Fusaria* have also come to our notice. Kendrick [1931, 1934] has shown that the wilt of cowpea and the yellows of beans, caused by species of *Fusarium*, are transmitted through the seeds. Kadow and Jones [1932] and Snyder [1932] have shown that the *Fusarium* wilt of peas is of similar nature. Taubenhaus and Ezekiel [1932] have shown that the cotton wilt organism is seed-borne. In India, Kulkarni [1934] has shown the seed-borne nature of cotton-wilt fungus. Mitra [1934] has proved that the *Fusarium* involved in wilted sunn-hemp is carried externally on the seeds. On the other hand, Uppal and Kulkarni [1937] have produced experimental evidence that the sunn-hemp wilt fungus can be carried both externally and internally through the seeds.

In pigeon-pea the seed transmissibility of the *Fusarium* is not definitely known. Butler [1918] writes that there is no evidence to prove that the wilt producing fungus in pigeon-pea is seed-borne. McRae [1924, 1926] showed that the bulk of infection does not come through the seeds; but this statement does not eliminate the idea that the fungus may be carried through the seeds. Moreover, McRae [1924] has shown that when the surface sterilized seeds were sown in presumably disease-free plots, the percentage of wilt was 0·04 per cent. This fact does not disprove that the fungus may be carried through the seeds. Furthermore, from the symptoms, a strong parallelism of pigeon-pea wilt to that of the cotton wilt is suggested. Kulkarni [1934] writes that in wilted cotton plants, the fungus spreads inside the diseased plants to the top, passing through pedicles into the seeds. In many cases also the fungus fails to reach the pedicles. In pigeon-pea almost a similar state of affairs takes place. The previous isolation experiments show that the fungus in many cases spreads internally to the top of the branches and there is every possibility of the organism spreading further into the pods and the seeds. Therefore, it was thought worthwhile to carry on experiments to ascertain if the fungus is borne inside the seeds of the diseased pigeon-pea plants.

In the topmost branches, the plant stem becomes gradually thinner and thinner and the isolation from these branches becomes difficult. Moreover, during the process of collecting the dead plants from the field, many of these thin branches break and fall down. Therefore to take isolations further upwards to the very base of the pods, becomes increasingly difficult and sometimes impossible. Hence it was thought desirable to study the seed transmissibility of the disease by direct methods.

We know that a fungus may be carried either externally or internally through the seeds; but the question of external seed transmission of the disease is not considered here because in the diseased plants which have long died there are abundant spores on the plant surface. During husking operations, there is every chance of the seeds getting contaminated with the spores from these diseased plants. Therefore the superficial transmission of the disease through the seeds will not be surprizing. With this assumption the experiment was confined to the study of the internal transmission of the disease in the seeds of the diseased plants.

Seeds from the diseased and healthy plants in the field were collected and they were classified into three groups as follows: (1) those from plants which have long died, having superficial pink coloration to considerable heights of about six feet; (2) those from the freshly wilted plants; (3) those from the normal healthy plants. These groups were designated B, C and N respectively. The seeds were surface-sterilized by immersing them for five minutes in 1 : 320 formalin solution and washing thoroughly in sterilized water.

In laboratory experiments, the sterilized seeds were placed in tube slants containing potato-dextrose-agar medium. Five hundred seeds of the group B and 300 seeds of group C. were thus treated. In all the 800 tubes, although the seeds swelled and burst in course of a fortnight, there was no indication of the fungus living inside the seed.

For pot-culture experiments, the soil taken from the field was soaked with water half an hour before sterilization and was sterilized by keeping it for one hour under 25 lb. of steam pressure. Then pots of convenient size were sterilized by dipping them for three to four minutes in a bucket of 1 : 320 formalin solution and these pots were filled up with the sterilized soil. Four hundred seeds of group B, 800 seeds of group C and 400 seeds of group N, were selected and immediately after their surface-sterilization they were sown, eight seeds in each of the pots. The seeds were sown on 3.7.1941 and the plants emerged from the soil after a week. The plants were kept under observation till 10.11.1941 when they were about 16 weeks old, and then the experiment was discontinued.

It was found that out of 400 seeds of group B, only 200 seeds were able to germinate, out of 800 seeds of group C. only 747 and out of 400 seeds of group N, only 350 seeds germinated.

In none of the plants raised from seeds of any class, was there any indication of wilt within the period of 16 weeks during which the experiment was conducted.

It was noted that the plants raised from the seeds of freshly wilted and healthy plants, were tall, robust, profusely branched and healthy looking; but the plants raised from the seeds of group B, were dwarfed, sparsely branched and not very vigorous. The average height of these plants after a period of 16 weeks was about four to five feet, whereas the height of the others was about six to seven and in some cases rising to eight feet.

The effect of temperature on survival and germination of spores formed on the surface of diseased plants

In an advanced state of the disease it is seen that the fungus comes to the surface of the plants and sporulates there freely. The majority of the spores are micro-conidia. These aerial diseased parts bearing abundant inoculum of spores, may prove to be potential sources of danger in the primary infection and perpetuation of the disease in a field, if these exposed spores remain viable from year to year. It is, however, expected that under natural conditions, of which the temperature is important, these surface exposed spores may be affected in their viability and germinability. In the experiments recorded here, the behaviour of micro-conidia at different temperatures was studied.

(*a*) *Determination of a suitable temperature for germination of micro-conidia.* From the surface of a diseased plant spores were scraped, and a suspension to a suitable concentration was made in sterilized water. One c.c. of this spore suspension was then poured and spread on the surface of a plain agar plate previously prepared. It was found by trial that the use of a synthetic medium encouraged free bacterial growth, and acidification of media with lactic acid did not check the bacterial growth satisfactorily without affecting the fungus spores. In the plain agar medium it was found that the bacterial growth was not so rapid. Furthermore, it was observed that when the spore suspension was mixed with the melted agar and then plated out, spores were very naturally placed at different depths of the medium in the same plate and under a particular field and under a particular focus, some spores came rightly to the focus, some slightly so and some not at all. This interfered with the counting of the germinating conidia. Therefore, in previously plated agar plates, 1 c.c. of the spore suspension was poured and uniformly spread, the extra water being poured off. These plates were then incubated at temperatures of 10°C., 15°C., 25°C. and 35°C., and the number of spores germinated was counted after 17 hours, 22 hours and 25 hours. The results of the experiment are indicated in Table IV.

TABLE IV

The percentage of germinated micro-conidia at different times under different temperatures

Temperature at which the plate was incubated	Average percentage of germination after 17 hours of incubation	Average percentage of germination after 22 hours of incubation	Average percentage of germination after 25 hours of incubation
10°C.	*Nil*	18·5	40·0
15°C.	26·1	33·0	58·4
25°C.	60·4	38·2	40·0
30°C.	67·1	55·0	41·7
35°C.	43·3	55·3	53·0

From Table IV it is observed that under all temperatures tried the percentage of germination falls down after 22 and 25 hours. This is because by this time, at these temperatures, considerable mycelial growth takes place and the mycelia begin to produce fresh conidia. Thus as the time passes on, the percentage of freshly produced conidia increases and this phenomenon is responsible for the low percentage counts in germination as the time is lengthened. Moreover, the rate of production of micro-conidia increases with the temperature, and the longer the duration of exposure, the greater is the disparity in the number of spores at the lowest and the highest temperature. Therefore the results on the percentage of germination became irregular after 22 and 25 hours of incubation and at these temperatures, the data as seen in Table IV, cannot be regarded as reliable. Moreover, at higher temperatures of 30°C. and 35°C., considerable bacterial growth takes place, and this goes on increasing with time and interfering with the counting. Hence the percentage of germination counted after 17 hours was regarded as fairly reliable and the conclusions were made thereon.

Analysis of the data after 17 hours shows that with the increase of temperature the percentage of germination, starting with zero at 10°C., increases up to 30°C. and then declines at 35°C. In other words, the percentage of germination is highest at 30°C. All subsequent spore germination studies were undertaken at the temperature of 30°C.

(*b*) *The effect of maintained temperatures on the germination of micro-conidia.* The pigeon-pea plants are harvested generally in the months of April and are sown in the months of June and July. The dead and the diseased residual aerial parts of the plants lie above or buried in the ground or are carried by some disseminating agent to other fields. After the month of April ungerminated conidia exposed on the source of the diseased plants have to pass through a critical period of summer months. Under local conditions of Delhi, the range of shade temperature varies from 30°C. to 45°C. in May and June, but the spores lie exposed in the sun at still higher temperatures. It is of interest to study if these surface-borne micro-conidia outlive the summer months and help in the perpetuation of the disease and in bringing about fresh infestations in the subsequent seasons. With this end in view the effects of maintained temperatures on the germination capacity of the micro-conidia were studied.

Some diseased stems of pigeon-pea having abundance of micro-conidia on the surface were collected from the field on 21.3.1942 and the materials were cut to a suitable size. These stems pieces were divided into four lots, one lot being kept in the laboratory exposed to the natural temperature conditions. Out of the three lots left one was kept in 10°C., another in 15°C. and the last in 20°C. First reading on the percentage of germination was taken on 21.4.1942, after their incubation for a month; the second reading taken on 20.7.1942, after four months of incubation and the last reading on 15.8.1942 after an incubation period of nearly five months. The technique followed in counting of germination percentage was the same as followed in case of determining a suitable temperature for the germination of micro-conidia. The results of the experiments are indicated in Table V.

TABLE V

Readings after different hours at 30°C. taken on the average percentage of germination of micro-conidia after they were subjected to different temperatures for a period of one month (21.3.1942 to 20.4.1942)

Constant temperatures to which spores were subjected	Average percentage after 8 hours	Average percentage after 10 hours	Average percentage after 12 hours	Average percentage after 15 hours
10°C.	57·3	74·78	85·1	89·7
15°C.	55·7	57·78	55·3	79·6
20°C.	32·8	55·3	62·4	77·0
Normal room temperature .	26·0	48·7	63·0	64·6

TABLE VI

Readings after different hours at 30°C. taken on the average percentage of germination of micro-conidia after they were subjected to different temperatures for a period of four months (21.3.1942 to 20.7.1942)

Constant temperatures to which spores were subjected	Average percentage after 8 hours	Average percentage after 10 hours	Average percentage after 12 hours	Average percentage after 15 hours
10°C.	14·6	25·9	31·4	41·8
15°C.	11·9	19·4	24·6	27·9
20°C.	5·9	7·5	20·3	25·6
Normal room temperature .	*nil*	3·2	15·3	21·1

TABLE VII

Readings after different hours at 30°C. taken on the average percentage of germination of micro-conidia after they were subjected to different temperatures for a period of nearly five months (21.3.1942 to 15.8.1942)

Constant temperatures to which spores were subjected	Average percentage after 8 hours	Average percentage after 10 hours	Average percentage after 12 hours	Average percentage after 15 hours
10°C.	17·0	21·5	26·5	31·8
15°C.	12·8	12·6	17·6	25·0
20°C.	*nil*	10·0	14·8	20·0
Normal room temperature .	,,	*nil*	*nil*	9·4

Tables V, VI, and VII show that the samples of micro-conidia kept at lower temperatures, retain their germination capacity better than those at higher temperatures. This fact is obvious from the comparative readings in any one of the tables. It is seen that the percentage of germination is the highest at the lowest temperature used and gradually decreases as the temperature, in which the conidia are stored, is increased.

The comparative studies of Tables V, VI and VII show that as the samples of micro-conidia are kept for a longer time at a particular temperature, the germination capacity of the spores is

reduced more and more. In the samples kept at the lowest temperature of 10°C. for a month the percentage of germination after 15 hours at 30°C. was 89·7 in April, this number decreasing to 31·8 in August after five months of storage. Similar was the case with the highest constant temperature used in this experiment. In the samples of micro-conidia stored at 20°C., the percentage of germination after 15 hours at 30°C. was 77·6 in April and 25·6 in July after four months of storage and 20·0 in August after five months of storage. These facts indicate that during a course of five months of storage at a particular temperature the germination capacity of micro-conidia is appreciably reduced and with the higher temperatures these changes become more marked.

Discussion

It is seen that in a pigeon-pea plant in an advanced stage of the wilt, the spores of *F. udum* can be found externally on the surface up to a height of five to six feet. The results of isolation experiments, as shown in Tables I and II, indicate that the external vertical distribution of the fungus, as judged by the presence of the spores on the plant surface, is always lower than the internal vertical distribution. This suggests that the superficial spores come after the fungus establishes and spreads inside the plant up to a certain height. This fact is further corroborated by the results obtained from the freshly wilted plant, where there are no superficial spores and the fungus is always present internally up to a certain height. Thus the idea that a spore, carried by air or water, germinates and that the fungus then spreads superficially on the aerial parts of the plants, is not supported by the evidence. Also, field observations show that this superficial sporulation of the fungus on the surface of the diseased plants comes late in the season, when the disease is fairly advanced.

Observations for two successive seasons in the pigeon-pea field of the Mycological Section at the Imperial Agricultural Research Institute, New Delhi, showed that in the following year the groups of diseased plants were found generally in the same spot where in the previous year one or more diseased plants were growing. These infested areas widened in diameter gradually from year to year. Therefore, in an infested field, diseased plants were found to lie always in patches, with a few stray plants attacked here and there. In subsequent years, in place of these stray plants, one would find two or more plants affected by the disease, depending on the rate at which the fungus had been able to grow in the meantime. This suggested that the stray diseased plants were the results of the current season's infestation, whereas the individuals in a group were the results of older infection.

In freshly wilted plants it is seen that a brown streak is present on the stem from the base of the plant upwards. The branches arising from these regions are those which wilt. The isolation studies, as seen from Table III, show that the fungus is present inside the vascular bundles in these blackened areas, whereas at the same height, but in other regions of the stem, the fungus cannot be traced. The facts suggest that in the beginning the fungus spreads inside and travels upwards in the regions of the vascular bundles and then spreads gradually to other portions of the stem. The branches coming in the path of advance of the fungus wilt one after another. This explains why, in a freshly wilted plant, there are some branches which are normal and healthy, whereas others are wilting.

Both laboratory and pot-culture experiments have shown that in pigeon-pea plants the wilt-producing organism is not carried inside the seeds. The experiments in pots were continued up to a period of 16 weeks, the age at which Mundkur [1935] has shown that under filed conditions, in a plot which is not naturally infested but artificially made so, the maximum percentage of wilt is attained. Affording all possible favourable conditions, not a single case of wilt was observed in the pots, showing that the fungus is not borne inside the seeds.

Experiments have shown that the fungus has been able to reach the top internally, only in the plants that died early, and only in some of the branches of some of the dead plants. In some of the diseased plants which died early, although the fungus has spread internally to considerable heights of about six to seven feet, this has not been able to reach the top. In those freshly wilted plants, the internal spread of the fungus is only about two to three feet above the ground. These facts

show that the fungus can spread saprophytically inside the plants after their death, and, further that considerable time elapses between the death of the plant and the arrival of the fungus at the top. Thus, assuming the fact that the ability of the fungus to reach the top is a post-mortem phenomenon, the life continuity of the seeds with the plant is broken before the fungus reaches the seeds. Under these conditions, if the seeds are immature, they will not get time to mature and will simply harden up due to the loss of water in course of time. If the fungus can enter the pods before the seeds dry up, it can make its entry through the soft integuments into the seeds; but the seeds, immature as they are, will never be able to germinate. On the other hand, if the seeds are mature by the time of the plant's death, the hard integuments of seeds will make it difficult for the fungus to get inside. Therefore for infection of the seeds we must expect the following conditions: (1) The fungus should reach the seeds before the plants die; (2) the seeds should be young and immature with their integuments soft so that the fungus can make an easy entry. Since the plants die before the fungus reaches the top and the organic connection of the seeds with the plant is severed with consequent discontinuity in seed nourishment, such conditions as outlined above probably never happen. Therefore, on purely theoretical grounds it seems that in the matured seeds which can germinate, the fungus cannot possibly be borne inside, even though it may be able to reach the top of the plants.

It was observed that about 50 per cent of the seeds collected from plants in an advanced state of the disease could not germinate and almost all the seeds from freshly wilted plants germinated normally. This seems to be due to the fact that in the plants which had died early, probably the seeds could not get time to mature properly, whereas in the freshly wilted plants, the seeds attained maturity before the disease could bring about the death of the plants. Therefore, the failure of some of the seeds collected from the diseased plants that died early, can rightly be ascribed to the immaturity of the seeds, and not to infection.

Furthermore, it was observed that the plants raised from the seeds of the diseased palnts that died early, were stunted in growth, less vigorous and sparsely branched; but the seeds from the freshly wilted plants gave rise to normal plants. The difference between these two groups of plants was the attack of the disease at different stages of their growth. The loss of vigour, dwarfing effect and others which were noticed in this case were perhaps due to the discontinuation of certain processes in that chain of reactions which takes place for the proper nourishment of the embryo and thus affects the vitality of the seeds.

When debris from diseased plants carrying abundant micro-conidia on the surface, was stored at different temperatures, the micro-conidia retained their germination capacity better and for a longer time at low temperatures. As the temperature in which the samples of micro-conidia were stored was increased, the percentage of germination after any particular hour at 30°C. gradually became less. Also when the period of storage at any particular temperature was extended, the germination capacity of the micro-conidia was gradually reduced. The germination of micro-conidia exposed to the normal room temperatures dropped appreciably after four to five months, though still a certain percentage of micro-conidia remained viable. The experiments were not carried far enough to determine whether under exposed conditions in the field spores may remain viable from one season to the next.

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Summary

(1) *Fusarium udum* Butler, which causes wilt of pigeon pea, forms abundant spore masses on the surface of infected plants.

(2) It was found that the spore masses occur only on branches of infected plants at a point considerably below that which the fungus has reached in the tissues, and it is concluded that the

spore masses do not form as a result of primary infection in the aerial parts, but arise as a result of the outward spread of the fungus from internally infected branches.

(3) The fungus was never found to be carried within the seeds.

(4) The conidia retain their viability for some months, but this falls off more quickly in normal room temperatures in summer months in Delhi than at a temperature of 20°C. or lower. It remains to be determined whether under field conditions they can survive from one crop season till the next.

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PHYSIOLOGICAL STUDIES IN GROWTH AND DEVELOPMENT OF CROP PLANTS

I. PHOTOPERIODIC INDUCTION OF DEVELOPMENTAL ABNORMALITIES IN INDIAN WHEAT

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(With Plate XXIV and two text-figures)

FROM early days observations have been recorded on branching and other abnormalities of the reproductive spike in cereals and other plants. An excellent summary of earlier work has been given by Bose [1935] who observed branched heads in Indian barley and studied the inheritance of this character in F_2 and F_3 generations. Hurd-karrer [1933] made observations on the growth of normal winter and spring bread wheats when kept under short (8 hour) and long (17 hour) day at constant low (12°C.) and high (21°C.) temperatures. She found that at both low and high temperatures, short days produced long heads, the lengthening being most pronounced at the low temperature and mainly due to an increase in the distances between the lowermost spikelets. Under conditions of short days and low temperatures a secondary head was sometimes produced from the axil of the topmost leaf, and in Turkey, the winter wheat used, the main heads were often branched giving " miracle " bread wheats. Long days produced very short heads. In the winter wheat used, long days and the higher temperature often led to a failure to produce heads at all but resulted in the development of an elongated shoot with multiple vegetative branching at the nodes. Tumanyan [1934] has shown that forms with branched ears were only known in *Triticum turgidum* and *T. dicoccum* till lately. In 1929, however, he found some true soft wheats from eastern Anatolia with branched ears, which peculiarity was transmitted to the progeny. A new sub-species, called *Triticum vulgare compositum* was established for these branched wheats which are also characterized

by earliness, drought resistance, high percentage of protein in the grain and stiff straw. McKinney and Sando [1934] found that certain varieties of wheat grown under daily photo-periods of less than 13 hours or under continuous light of low intensity brought about twisting of the internodes at the base of the rachis in some of the tillers of a single plant. From the fact that not all varieties showed twisting under these conditions it was assumed that heritable factors were involved. The phenomenon of twisted trees has been considered by these workers in the light of the results on wheat. Biddulph [1935] working with plants of klondike variety of *Compositæ sulphureos* found that when they were transferred from short to long photo-periods several abnormalities developed including changes in the phyllotaxy, elongation and foliation of bracts, twin flower-heads and elongated internodes in the regions of the involucral bracts. Murneek [1940], on the other hand, demonstrated that Rudbeckia plants when transferred from long to 7-hour day either failed to flower or bore vegetative flowers, while some formed the usual type of flowers. By slowing down thermo-and photo-phases in wheat and rye, Zabluda [1940 and 1941] was able to produce abnormalities in spike structure, such as, the formation of true leaves at the base of the spike, conversion of spikelets into spikes and of spikelet scales into leaves. Recently Sharman [1944] obtained branched or normal heads of wheat in an F_1 progeny of a cross between a normal bearded bread wheat (*Triticum vulgare* Host, 2n=42) and a branched or 'miracle' headed Rivet wheat (*T. turgidum* L., 2n=28) by altering the time of sowing. This branching of ears was noticed only on the main stem. Tillers gave rise to normal heads in all cases. He concluded that the expression of this character was greatly influenced by the day-length and perhaps the temperature under which the plants were growing. He postulated that the branched-headed factor operated by altering the branched/normal-headed threshold and so could be made to behave as either a dominant or a recessive at will. As a result of extensive work on the interspecific crosses of wheat (*T. vulgare* x *T. vavilovianum* and *T. vulgare* x *T. spharococcum*), Pal and his associates at this Institute (unpublished work) have demonstrated that the compound spikelets of *T. vavilovianum* are inherited in the F_2 and F_3 generations and that the degree of compounding of spikelets in the crosses as well as in the species itself (*T. vavilovianum*) is greatly influenced by environmental and soil conditions.

It becomes clear from the above review that although some of these abnormalities may be genetic in nature they are in the main controlled by environmental factors, especially light and temperature. During the course of studies on photo-periodic responses of wheat at this Institute such abnormalities appeared in plants under certain photo-treatments. It was, therefore, decided to investigate the cause of these abnormalities, particularly with reference to their relation with the phasic development of wheat.

Experimental procedure

Graded seed of three pure line varieties of wheat (*Triticum vulgare* var. I.P. 165, I.P. 52 and P.C. 591) were germinated in Petri dishes, on a thin layer of sterilized sand.

Twenty-five seeds falling within a range of 45-50 mg. weight were placed in each Petri dish, watered with 5 ml. of distilled water and exposed immediately to the following photo-periodic treatments, (i) complete darkness, (ii) 6-hour daily illumination alternating with 18 hours of darkness, (iii) almost equal periods of light and darkness (normal day-light of October-March at Delhi), (iv) 18 hours of daily illumination alternating with 6 hours of darkness (normal day-light supplemented by artificial illumination from four 200 watt. day-light bulbs at a mean distance of 2 ft. from the seed for a requisite period), (v) continuous illumination (24-hour light period). After the completion of the above light treatments which have been called photo-inductive treatments, the seedlings were transplanted in unglazed pots and exposed to: (*a*) a short day (SD) with a 6-hour period of illumination, (*b*) normal day (ND) with almost equal periods of light and darkness, and (*c*) long-day (LD) either 18 hours or 24 hours of illumination as shown for different experiments. Full details regarding number of seedlings and pots used, growth measurements and length of different treatments are given separately for each experiment. Different combinations of photo-inductive and post photo-inductive treatments are described in the text by combining the serial number

of the former with the abbreviation of the latter. Thus for instance : 1-SD means that the seedlings were kept in complete darkness during the period of photo-inductive treatment and were subsequently exposed (post photo-inductive treatment) to a short day, 5-LD means that the seedlings received continuous illumination during the photo-inductive treatment and a long day during the period of post photo-inductive treatment and so on.

Experiment No. 1 (1941-42)

Varieties used. Three-I.P. 165, I.P. 52 and P.C. 591 (*T. vulgare*).

Photo-periodic treatments: 135 Petri dishes containing 25 graded seed (45-50 mg.) were moistened with 5 ml. of water and placed under the five photo-inductive treatments described above for the first 12 days. Thus 27 Petri dishes (nine for each of the three varieties) were placed under each treatment. The three post photo-inductive treatments already described were started immediately after the transplantation of seedlings in pots.

Growth observations

Mean period between the day of sowing and the day of first anthesis in 10 plants selected at random was taken as vegetative period for each treatment.

Number of spikelets and number of grains in the ears of five plants were counted and mean values per ear were obtained. Mean length of ear was also derived from observations on five plants. Results are presented in Table I.

It will be observed that the vegetative period is determined by the length of the day. Even the photo-inductive treatments which are of shorter duration compared to the post photo-inductive treatments reduce the vegetative period. Number of spikelets and grain per ear as well as the length of the ear are all appreciably reduced in all combinations of photo-inductive treatment with subsequent long day (LD) in all the three varieties.

The above analysis (Table II) clearly reveals that both the photo-periodic treatments have a significant effect on ear development both as regards the number of spikelets as well as the length of ear. Although analysis of variance for the grain number as well as for the vegetative period have not been presented here, it has been carried out and in the case of the former it follows a parallel course with the number of spikelets per ear. LD treatment causes a reduction in number of spikelets ear length, grain number and vegetative period.

Experiment No. 2 (1942-43)

In order to confirm the results obtained in 1941-42, experiment No. 1 was repeated during 1942-43 with very few modifications.

Photo-periodic treatments

Only three photo-inductive treatments Nos. 1, 3, and 5 were used in this experiment. Duration of treatment was increased in each case to 14 days. SD and ND treatments were the same as in experiment No. 1. LD treatment was, however, continuous light instead of 18-hour day. In all 81 Petri dishes with 25 seeds in each were exposed to different photo-inductive treatments (27 each variety).

Growth observations were the same as in experiment No. 1. Ten plants were used for determining spikelet and grain numbers as well as the length of the ear.

TABLE 1

Development of the spike of three varieties of wheat under differential photo-periodic treatment (1941-42)

Photo-inductive and post photo-inductive treatment	Vegetative period (days)			Earliness over control (1—SD) (days)			No. of spikelets per ear			No. of grains per ear			Length of ear (cm.)			Abnormalities, if any
	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P.52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	
1—SD . .	99·1	105·2	113·7	..	..	..	14·0	15·0	16·0	7·9	21·2	4·0	7·2	6·4	6·2	Normal ears
2—SD . .	98·7	102·2	113·0	0·4	3·0	0·7	15·2	17·0	18·2	13·8	19·6	16·8	7·0	6·9	7·2	Ditto
3—SD . .	98·5	97·8	108·2	0·6	7·4	5·5	17·0	19·0	19·0	14·6	20·6	17·0	8·8	7·4	8·2	Ditto
4—SD . .	96·4	97·3	107·2	2·7	7·9	6·5	16·0	15·8	19·8	15·9	13·3	..	7·9	6·2	7·9	Ditto
5—SD . .	87·5	93·3	105·4	11·6	11·9	3·3	16·0	15·4	18·2	16·2	9·5	9·5	8·8	6·0	7·1	Rachis between 1st and 2nd spikelets of main ear elongated
1—ND . .	81·6	87·7	96·4	17·5	17·5	17·3	16·6	17·8	15·8	24·8	31·0	23·0	9·5	7·2	7·4	Normal ears
2—ND . .	78·1*	84·0	95·8	21·0	21·2	17·9	16·4	19·0	17·0	28·4	29·9	27·6	9·2	7·3	8·0	Ditto
3—ND . .	70·9	79·5	89·3	28·2	25·7	24·4	19·4	19·4	16·8	28·3	30·8	25·6	10·1	7·5	8·3	Ditto
4—ND . .	70·0	77·7	84·8	29·1	27·5	28·9	19·0	19·8	19·0	28·5	32·8	..	9·5	7·9	9·1	Rachis elongated in I.P. 52 and P.C. 591
5—ND . .	66·7	67·8	78·9	32·4	37·4	34·8	18·6	17·0	20·2	23·1	21·2	28·3	8·8	5·9	8·2	Rachis elongated in all varieties Branched main ear in I.P. 52 Compound spikelets in P.C. 591
1—LD . .	61·2	60·5	65·2	37·9	44·7	48·5	12·6	14·2	14·6	6·6	4·1	5·1	6·3	5·0	6·3	Short ears
2—LD . .	56·0	57·1	65·3	43·1	48·1	48·4	13·4	13·8	13·4	8·9	5·3	10·0	6·8	5·7	6·7	Ditto
3—LD . .	54·5	55·7	63·9	44·6	49·5	49·8	15·0	13·8	15·4	8·1	8·5	9·2	8·0	5·8	7·0	Ditto
4—LD . .	53·7	54·8	..	45·4	50·4	..	15·8	15·4	14·4	6·6	7·5	..	8·6	5·4	7·5	Ditto
5—LD . .	50·0	50·4	54·9	49·1	54·8	58·8	17·0	13·4	16·2	6·4	9·3	8·3	7·5	5·4	7·0	Ditto

TABLE II

Analysis of variance of spikelet number and ear length (Table I)

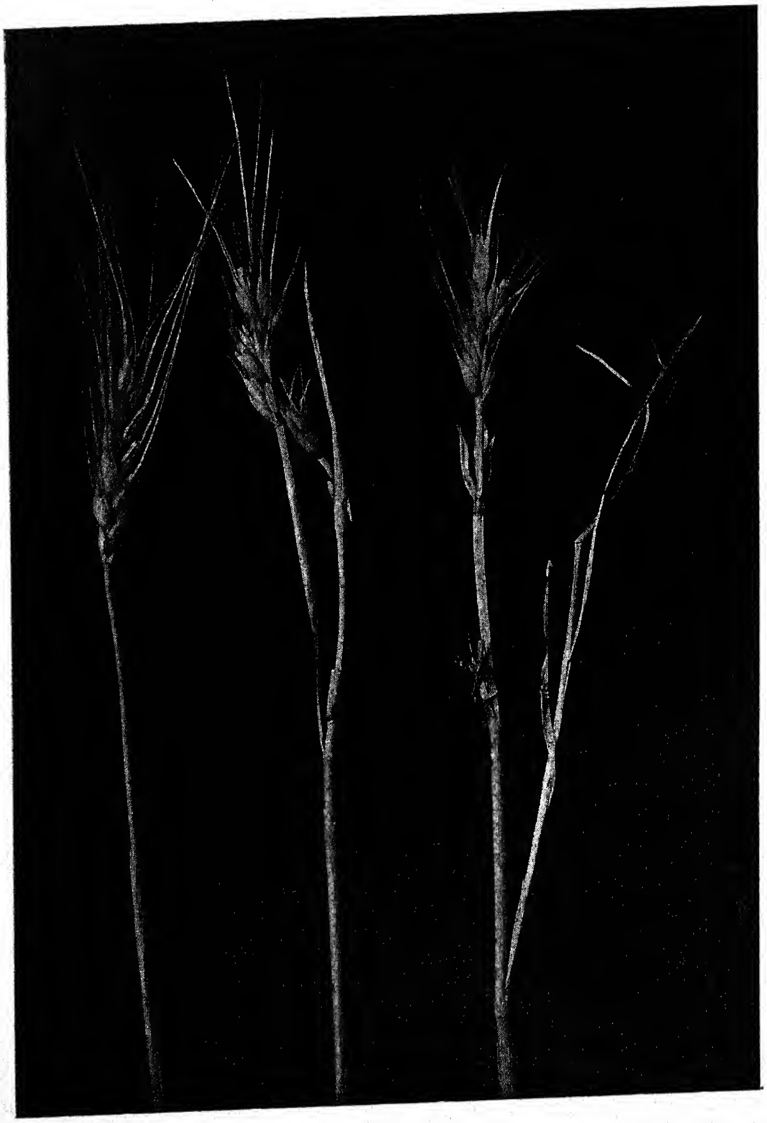
No.	Treatment	Degrees of freedom		Sum of squares		Mean square		Treatment variance / Error variance	
		Spikelet No.	Ear length	Spikelet No.	Ear length	Spikelet No.	Ear length	Spikelet No.	Ear length
1	Replicates	4	4	7·9	0·54	1·98	0·14	1·4	0·5
2	Post photo-inductive treatment	2	2	484·6	105·18	242·30	52·59	177·1 S	194·0 S
3	Photo-inductive treatment	4	4	145·4	36·00	36·35	9·00	26·5 S	33·3 S
4	Varieties	2	2	25·0	132·49	12·50	66·24	9·1 S	245·0 S
5	Interaction : 2 × 3	8	8	48·2	11·87	6·03	1·48	4·4 S	5·4 S
6	Interaction : 2 × 4	4	4	80·4	7·77	20·20	1·94	147 S	7·2 S
7	Interaction : 3 × 4	8	8	83·2	16·54	10·40	2·07	7·6 S	7·6 S
8	Interaction : 2 × 3 × 4	16	16	68·6	14·37	4·30	0·90	3·1 S	3·3 S
9	Error	176	176	240·9	47·86	1·37	0·27	..	..
	TOTAL	224	224	1184·2	372·62	..	..	..	..

S denotes highly significant effects of treatments and interactions (P LO·01).

TABLE III

Development of the spike of three varieties of wheat under differential photo-periodic treatment (1942-43)

Photo-inductive and post photo-inductive treatment	Vegetative period (days)			Earliness over control (1—SD) (days)			No. of spikelets per ear			No. of grains per ear			Length of ear (cm.)			Abnormalities, if any
	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591.	I.P. 165	I.P. 52	P.C. 591	
1—SD	116·7	118·5	134·6	..	..	..	15·7	12·6	9·9	28·2	14·0	6·5	6·4	4·5	3·7	Normal ears
3—SD	107·5	99·1	111·0	9·2	19·4	23·6	16·0	16·4	14·7	31·1	20·1	22·1	9·5	6·0	7·1	Ditto
5—SD	104·9	95·8	101·6	11·8	22·7	33·0	16·4	13·6	14·6	31·3	21·6	24·1	9·5	5·7	5·9	Rachis between 1st and 2nd spikelets of main ear elongated
1—ND	87·5	93·1	100·3	29·2	25·4	34·3	16·1	17·1	15·2	30·8	34·1	30·0	9·4	6·9	6·9	Normal ears
3—ND	84·8	89·8	95·4	31·9	28·7	39·2	16·4	17·7	16·0	29·4	40·2	30·5	9·3	7·1	7·6	Ditto
5—ND	79·1	81·7	85·4	37·6	36·8	49·2	15·1	17·5	17·7	26·1	36·0	38·1	8·6	7·0	7·7	Rachis elongated. Compound spikelets in P.C. 591. Branched ear in I.P. 52
1—LD	78·0	77·6	74·7	38·7	40·9	59·9	8·5	8·0	8·9	9·4	10·6	14·9	6·3	4·5	5·5	Short ears
3—LD	62·2	67·2	66·5	54·5	51·3	68·1	11·4	9·8	10·7	6·6	9·6	13·4	6·3	4·8	5·6	Ditto
5—LD	60·8	63·0	67·0	55·9	55·5	67·6	8·6	9·9	10·5	9·2	13·4	15·2	5·8	4·4	5·3	Ditto



A B C

FIG. 1. Branching of ears in I P 52 wheat under photoperiodic treatment; A, ear from 5-LD treatment, B, ear from 5-ND treatment (Experiment No. 1) and C, ear from 5-ND treatment (Experiment No. 2)

TABLE IV

Analysis of variance of spikelet number and ear length (Table III)

No.	Treatment	Degrees of freedom		Sum of squares		Mean square		Treatment variance / Error variance	
		Spikelet No.	Ear length	Spikelet No.	Ear length	Spikelet No.	Ear length	Spikelet No.	Ear length
1	Replicates	9	9	58·96	19·13	6·55	2·12	0·68	1·9
2	Post photo-inductive treatment	2	2	2283·12	272·66	1141·56	136·33	118·40 S	126·2 S
3	Photo-inductive treatment	2	2	170·76	48·77	85·38	24·38	8·86 S	22·5 S
4	Varieties	2	2	21·45	249·32	10·72	124·66	1·10	115·4 S
5	Interaction : 2 × 3	4	4	47·66	75·55	11·91	18·89	1·20	17·5 S
6	Interaction : 2 × 4	4	4	162·24	39·66	40·56	9·91	4·20 S	9·1 S
7	Interaction : 3 × 4	4	4	71·33	3·92	17·83	0·98	1·85	0·9
8	Interaction : 2 × 3 × 4	8	8	81·05	20·77	10·13	2·59	1·05	2·4
9	Error	234	224	2256·84	254·33	9·64	1·08	..	..
	TOTAL	26	269	..	..	..	..	..	..

S denotes highly significant effects of treatments and interactions ($P < 0·01$).

Results of this experiment (Table III) fully corroborate the findings of the previous year (Table I) in that the post photo-inductive treatment LD in combination with all the three photo-inductive treatments causes a highly significant reduction in the spikelet and grain numbers as well as in the length of the ear. Other abnormalities which will be described presently are also reproduced especially when the plants are transferred from a long photo-period (Treatment No. 5) to post photo-inductive treatments with shorter photo-periods (SD and ND).

Experiment No. 3 (1942-43)

The occurrence of branching of main axis and other abnormalities in plants under 5-SD and 5-ND treatments (Table I and Plate XXIV, fig. 1) and absence of these abnormalities under other light treatments gave an indication of the existence of a critical state in the formation of reproductive primordia. This result has been subsequently confirmed by results of experiment No. 2. Experiment No. 3 was designed to determine the length of the photo-inductive treatment (No. 5) necessary for causing a significant change in the development of the spike.

Variety. Only one variety I.P. 52 wheat which gave very good response to light treatments was selected for this work.

Photo-periodic treatment : Germinating seeds (in 42 Petri dishes) were kept under continuous illumination for varying number of days ranging from one day to the whole growth period. There were in all 14 treatments as indicated in the first column of Table V. After the completion of each photo-inductive period the plants were transferred to normal day illumination for the rest of their growth period.

Growth observations were the same as in experiment No. 1.

TABLE V

Critical photo-inductive period causing reduction in spikelet and grain number as well as in ear length (1942-43)

Photo periodic treatment	Vegetative period (days)	Earliness over control (days)	No. of spikelets per ear	No. of grains per ear	Length of ear (cm.)	Abnormalities, if any
All normal days	91·7	..	19·0	46·0	7·2	Normal ears
1. Long day and than N.D. .	89·4	2·3	18·5	44·7	7·3	Ditto.
2. Long days Ditto .	87·3	4·4	18·3	43·6	8·1	Ditto.
3. Ditto .	87·6	4·1	18·5	43·9	7·5	Ditto.
4. Ditto .	93·6	1·9	18·8	42·6	7·2	Ditto.
5. Ditto .	88·1	3·6	19·6	46·1	7·4	Ditto.
6. Ditto .	88·3	3·4	19·1	43·6	7·2	Ditto.
7. Ditto .	86·0	5·7	18·3	43·6	6·6	Ears slightly shorter
8. Ditto .	84·0	7·7	18·3	43·4	6·7	Ditto.
9. Ditto .	84·6	7·1	18·6	42·8	6·5	Ears short Rachis elongated
10. Ditto .	82·8	8·9	17·4	42·3	6·3	Ears short Rachis elongated
13. Ditto .	81·9	9·8	16·9	39·9	6·2	Main ears very short Rachis markedly elongated Branching of main ears
20. Ditto .	78·1	13·6	14·6	28·1	5·8	Main ears very short Rachis markedly elongated No. of spikelets in the main ear reduced to 4-5 Branching of main ears
All long days	63·0	28·7	9·8	13·4	4·3	Ears very small but without any abnormalities like branching

The ears become shorter in photo-inductive treatment with seven long days, and progressively become shorter and shorter as the photo-inductive treatment is prolonged. Reduction in numbers of spikelets and grains is, however, noticeable in the photo-inductive treatment with 10 or more days of continuous illumination. It would be well to remember here that figures for the number of spikelet and grain are average of all the ears of 10 plants. If only the main ear is considered there is a far greater reduction in spikelet and grain number than shown in the tables of results given here.

Branching of ears and other abnormalities

Over and above the shortening of ears and reduction in the number of spikelets and grains certain other abnormalities have been observed which are described in the last columns of Tables I, III, and V as well as shown in Figures 1, and 2.

When I.P. 52 plants are transferred from No. 5 (24 hour-day) photo-inductive treatment to SD (6 hour-day) treatment the rachis between the 1st and 2nd spikelets (counting from the base) gets elongated. Branched ears are obtained in the same variety if the plants are transferred from No. 5 photo-inductive treatment to normal day. When the plants of the same variety are continuously kept under long-day conditions (as in 5-LD treatment) no abnormality in spike development other than the shortening of the ear and the reduction in the number of spikelets and grains occurs. The abnormalities in the development of the spike of I.P. 52 wheat under different photo-periodic treatments are shown in Plate XXIV. On the left hand side an ear (A) from 5-LD treatment is shown which is characterized by reduction in the number of spikelets and the ear length. In the centre a branched ear (B) from 5-ND treatment of experiment No. 1 is shown. On the right hand side a branched ear (C) of the same variety observed in 5-ND treatments of experiment Nos. 2 and 3 is shown. An interesting feature of the branched ear (C) for 1942-43 is that two vegetative branches have been given out (Plate XXIV, fig. 1-C).

In the case of I.P. 165, abnormalities were least noticeable. Except for the elongation of rachis between the first and the second spikelet under 5-SD and 5-ND treatments (Tables I and III), which was sometimes quite pronounced, no other abnormality was noticed.

In P.C. 591, over and above the usual elongation of rachis between the first and the second spikelet under 5-SD and 5-ND treatments (Tables I and III) compound spikelets appeared under 5-ND treatment (Fig. 1).

FIG. 1.

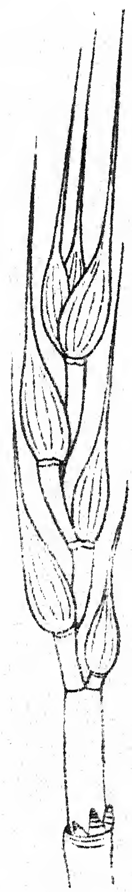


FIG. 2.

It is worthy of note that in all these cases such abnormalities were observed only in the spike of the main shoot. All the ears developing from the tillers of the same plant were apparently normal although there was a reduction in their size and also in the number of spikelets and grain.

In experiment No. 3 abnormalities such as branching of ears on the main stem began to appear only when the photo-inductive period of continuous illumination was longer than 10 days. In experiment Nos. 1 and 2 in which branching of ears was also observed, the photo-inductive periods of continuous light was of 12 and 14 days respectively. In other words the presence of a threshold light value is indicated for the production of such abnormalities. A few plants from all the treatments (of experiment No. 3) were dissected out at the shooting stage for studying the growth of the spike. No abnormalities were observed in any treatment except in plants which had received 15 and 20 days of continuous illumination as photo-inductive treatment, where a number of primordia

(2 to 4) appeared at the base of the main ear-head. A diagramatic representation of this abnormality is given in Fig. 2 which is drawn on a magnified scale (x 10) to make the growing points visible.

General discussion

As already stated in the introductory part of this paper, abnormalities generally appear as a result of changes in environmental conditions, especially photo-periodic in nature [Biddulph, 1935; Murneek, 1940; Zabluda, 1940-41; Hurd-karrer, 1933; Sharman, 1944; and McKinney and Sando, 1934]. In the present investigation as well as in a previous communication by Nanda and Chinoy [1945], abnormalities have been observed when the photo-periodic treatment was changed from continuous illumination to a subsequent short or a normal day (5-SD and 5-ND tratments, of Tables I and III and photo-inductive treatment of 15 to 20 days of continuous illumination in Table V).

The above evidence suggests a causal connection between the phasic development of wheat and these abnormalities. According to Lysenko (*Imp. Bur. Pl. Genet. Bull.* No. 17, 1935) "the qualitative changes occurring in the cells of the embryo at the time of vernalization constitute some permanent change of state which is transmitted to all later generations of cells throughout the life of the plant". Ljubimenko (quoted from *I.B.P.G. Bull.* No. 17) differing from Lysenko in his interpretation of the change occurring during vernalization has given considerable amount of evidence to demonstrate the impermanent and reversible nature of thermal and photo-periodic induction effects which are comparable to Lysenko's vernalization effects. Litvinov, Konstantinov, Bassarskaja, Gavrilova, Capikova and Zerling and Novikov (*Imp. Bur. Pl. Genet. Bull.* No. 17, 1935, pp. 39, 40, 47, 49, 79, and 82) and Gregory and Purvis [1938] have demonstrated the reversibility of changes occurring during vernalization. It, therefore, appears that there is a critical phase in the development of a young cell when it can be moulded into a vegetative or a reproductive organ depending upon the stage to which the qualitative change has proceeded in the cell during the induction period.

Evidence presented here (5-LD treatment of Tables I and III and the last treatment —all long days—of Table V) clearly demonstrates that the induction treatment when carried beyond a certain stage would affect a permanent change in all the later generations of cells. No abnormality such as branching of ears or elongation of rachis is, therefore, noticeable in such treatments. The reversible nature of the qualitative change, however, becomes apparent when the plants are transferred from long to a comparatively shorter photo-period, as in 5-SD and 5-ND treatments as well as in a photo-inductive treatment of 15 to 20 days of continuous illumination (Table V). Here branching of the main ear is observed, whereas all other ears arising from tillers are structurally normal. It can, therefore, be assumed that the induction effect has not been fully transmitted to all later generations of cells, as maintained by Lysenko. Neither Lysenko's concept of irreversibility of vernalization nor Ljubimenko's idea of the reversibility of induction effect can satisfactorily explain these evident disturbances in the symmetry of growth and development of a plant. The concept of hormonal regulation of growth and development is now generally recognized [Cholodny, 1939, and Gregory and his associate, 1937 and 1938].

The nature of the qualitative change under discussion here can, therefore, be explained by postulating that a change in the photo-periodic treatment brings about an alteration in the rates of production and of utilization of the regulatory substance, thus affecting its concentration in the growing points. Such a change in the concentration of the regulatory substance is likely to cause disturbances in growth and developmental symmetry of a plant. The response obviously will vary with the genetic constitution.

Summary

1. Photo-inductive and post photo-inductive treatments were given to three varieties of wheat (*T. vulgare*), I.P. 165, I.P. 52 and P.C. 591 for varying periods and the influence of these treatments on vegetative period, number of spikelets and grains per ear, as well as its length were recorded.

2. Under long-day conditions (5-LD) number of spikelets and grain and the length of the ear were considerably reduced. There were no other structural abnormalities under continuous long-day treatment.

3. If, however, the plants were transferred from a long day to a short or a normal day, different types of abnormalities, such as, branching of ear (Fig. 1), elongation of rachis (Tables I, III, V) and compounding of lowermost spikelets (Fig. 2) made their appearance.

4. The presence of a threshold light value for the production of such abnormalities is indicated by the fact that a photo-inductive period of 12 to 20 days of continuous illumination is necessary for producing them.

5. It is postulated that such disturbances in the symmetry of growth and development are brought about by changes in the concentration of regulatory substances in growing points under the influence of an altered photo-period, differential response being given by different genotypes.

ACKNOWLEDGEMENT

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CRYPTOSTEGIA GRANDIFLORA R. BR., A WAR TIME SOURCE OF VEGETABLE RUBBER

VI. YIELD OF LATEX AND RUBBER

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(With Plates XXV and XXVI)

THE detailed investigations on *Cryptostegia grandiflora* were undertaken at the instance of the Department of Supply. A search of the literature showed that Jumelle [1913] had found 2 per cent of rubber of inferior quality while Dolley [1925, 1927] discussed the commercial possibilities of the plant and described the results of analysis of a sample of rubber. Polhamus [1934] mentioned the rubber content of leaves of the four species while analytical data of solid rubber and vulcanisation tests were given by Trumbull [1942]. This little information gave no guidance for the formulation or development of methods for the production of rubber from the plant.

A plan for obtaining rubber by direct and indirect methods was prepared. The former consisted of a tapping programme while the latter included production of rubber by mechanical extraction or bacterial decomposition or fermentation of the *Cryptostegia* material. The results obtained under the latter were embodied in Parts III and V of this series while those of the former were described partly in Parts I and II and are partly given in this investigation as well.

Tapping or method for the collection of latex from laticiferous plants is very old. ' Of the various methods of tapping rubber trees, that which with a similar amount of work, yields the greatest amount of good rubber over a longer period of time and which damages the tree the least (so that plantation will remain productive the greatest possible length of time) is in general to be designated as the most rational ' [1934]. In *Hevea* the latex used to be drawn by the herring bone, the repeated ' V ' and the spiral cuts, but now these methods have been abondoned and the form of cut most generally used consists of a horizontal or inclined cut from left to right in the bark and the latex slowly oozes out and trickles down into a cup placed below (Plate XXVI, figs. 1 and 2). In the case of *Cryptostegia* the bark tapping method is not possible owing to the small girth of an irregular and corrugated trunk of even 30-40 years old plants and also to the fact that on injuring the bark of the trunk only very tiny dropets of latex come out and the flow of latex occurs at active centres of growth (Plate XXV, figs. 1 and 2) show *Hevea* trees and *Cryptostegia* shrubs.

A microscopic study of laticiferous plants has revealed that the latex occurs in cells, tubes and vessels. The cells are not interconnected and the latex flows from them when they are opened by a cut and so plants with cells cannot be tapped like those provided with tubes and vessels. In plants with tubes and vessels the laticiferous system forms a net work of channels which run through the body of the plant and yield a large quantity of latex when cut. A study of longitudinal sections of *Cryptostegia* and *Hevea* (Plate XXV, figs. 3 and 4) revealed that in the latter the latex vessels which form a net work of channels are confined mostly to the outer and inner bark of the stem while in the former they are branched and are distributed in the cortex in the secondary phloem and in the pith. There are relatively more cells in the pith than in the bark and therefore tapping is best done by the clipping of the branches rather than incising the bark as in the case of *Hevea*.

Every part of *Cryptostegia* yields latex but its flow is more from tender twigs of the size of an ordinary pencil than from the old ones, pods, leaves, or trunk. On bleeding a tender whip the latex drips for about two minutes yielding 6-12 drops for the first cut (5-6 drops in old twigs and green seed pods) but further four cuts in succession gave 4, 4, 2 and 1 drop respectively (old twigs none, seed pods 2 and 1). Subsequent clipping gave no more drops due to the thickening of latex and its coagulation at the cut end. This coagulated latex after drying forms a plug. When the plug is pulled out a drop or two of latex oozes out but better flow occurs when a bit about an inch is nipped off. It was also observed that from the growing point of a whip at a height of 27 ft. of a four years old plant which had the support of a wall only 2 drops of latex were obtained in two minutes and a half and none on subsequent clipping of the same whip.

For the collection of latex 3 or 4 twigs are clipped off by a pruning scissors. They are thrust into the mouth of the test tube and latex collects in it (Plate XXVI, fig. 3). Bamboo tubes six inches in length with an internal bore of one inch were later substituted for glass tubes (Plate XXVI, fig. 4) which even if it were possible to avoid breakages, become too hot in summer and too cold in winter. They are easy to handle and non-breakable but the difficulty of cleaning them may be considered a defect. Further they are liable to split with changes in temperature and humidity, but that can be prevented by binding them with wire.

Employing the foregoing technique experiments were undertaken to ascertain (*a*) the best part of the day suitable for tapping, (*b*) effect of tapping on regeneration and growth of shoots, (*c*) the effect of frequency of tapping, and (*d*) seasonal variations affecting the yield of latex. The following conclusions were drawn:

(*a*) *The best part of the day suitable for tapping.* When different bushes are tapped either daily or on alternative days, the yields of both latex and rubber are more from the afternoon than from the morning tappings. If, however, the same bushes are continuously tapped even on alternate days, the yields are more from the morning tappings.

FIG. 1. *Hevea* trees—normal source of rubber

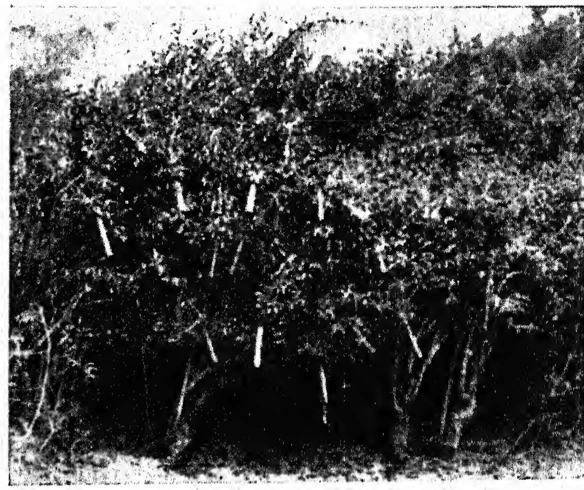

FIG. 2. *Cryptostegia*-shrubs, emergency source of rubber

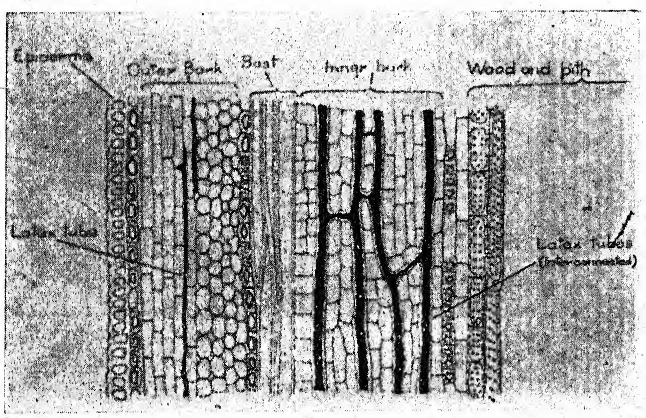

FIG. 3. Latex-bearing vessels of *Cryptostegia*

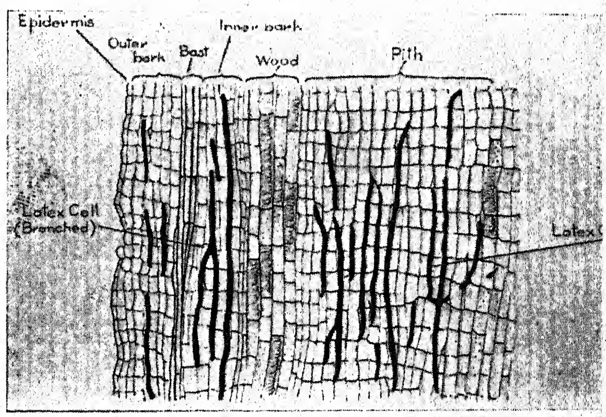

FIG. 4. Latex-bearing vessels of *Hevea*

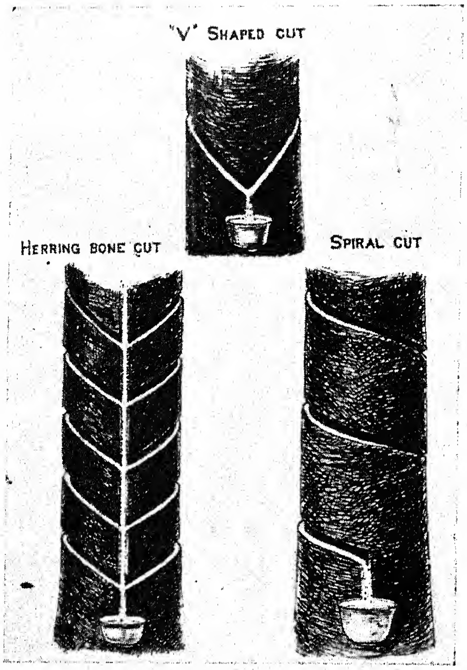

FIG. 1. Tapping of latex in *Hevea* by V-shaped, herring-bone and spiral cuts

FIG. 2. Tapping of latex in *Hevea* (in cups)

FIG. 3. Tapping of latex in *Cryptostegia* in glass tubes

FIG. 4. Tapping of latex in *Cryptostegia* in bamboo tubes

(*b*) *Effect of tapping on regeneration and growth of shoots.* The experiments conducted by the Botany Division of this Institute revealed that under any system of tapping regeneration is quick and that there is no serious adverse effect on regeneration although the tendency is for the untapped runner to develop more sprouts than the tapped one. Further, of plants pruned at 6 in., 9 in., 12 in. and 24 in. levels above the ground, those pruned at the 12 in. level are better as regards regrowth and the number of the whips formed and pruning away non-whip branches does not show any advantage so far as growth of whips is concerned. The pruning of whips (when they attain a reasonable stage of maturity) at about 6 nodes from their origin give a larger number of whips for plants than the unpruned controls.

(*c*) *Effect of frequency of tapping on the yield of latex and rubber.* The third system of tapping is economical from view points of yield, labour and strain to the plant.

(*d*) *Seasonal variations affecting the yield of latex.* The plantation of *Cryptostegia* at Okhla (Delhi) was divided into a number of blocks and the work was done under the supervision of the Rubber Directorate of the Supply Department.

Mixed tapping programme (alternate and third day) was started of blocks 1 and 12 on the 22nd April, 1943, and was continued till 17th July and on the following day purely alternate daily tapping was started of fresh blocks 2 and 10 which was continued till about the middle of June, 1944. In March 1944, two more blocks (12 new, 1 new) were brought under this tapping. On the other hand, third daily tapping of blocks 3 and 4, 5 and 6 and 9 and 11 commenced in the second week of November, 1943, and in April, 1944 was supplemented by blocks A, B and C. Thus the two systems of tapping was commenced in a number of blocks in different seasons of the year with a view to finding out the effects of seasonal variations and other physical factors on the yield of latex, rubbe , and plugs.

For seasonal changes the following dates have been assumed. Summer 15th April-14th June, rainy season 15th June-14th August, autumn 15th August-14th October, winter 15th October-14th February and spring 15th February-14th April. If only two seasons, summer and winter are reckoned in one year the former would range from 15th April to 14th October and the latter from 15th October to 14th April. The average yield of blocks for one month of the two systems, during various seasons are given in Table I.

The averages of tapping data in Tables I and II are calculated from the observations recorded at Okhla by Capt E. P. Hosken while dry rubber content (D. R. C.) percentages were determined in the Chemistry Division of the Imperial Agricultural Research Institute.

Table I

Average yield for one month per 1000 shoots of Cryptostegia

Average yield for one month during	Yield per 1000 shoots			D.R.C.	Name of block	System of tapping
	Latex	Rubber	Plugs			
Full summer including rainy season and autumn (15th April to 14th October).	128·4	5·6	11·3	4·4	1 and 12 2 and 10	Mixed alternate daily
Full winter including spring (15th October—14th April).	191·2	15·4	9·8	8·4	2 and 10	Alternate daily
Ditto	149·4	12·6	6·2	8·5	3, 4, 5, 6, 9 and 11	Third daily
Summer (15th April—14th June)	127·9	6·9	14·3	5·4	2 and 10	Alternate daily
Ditto	119·9	4·5	26·9	3·8	1 and 12 new	Ditto
Ditto	123·9	8·3	7·1	6·7	3 and 4, 5 and 6, 9 and 11	Ditto Third daily
Ditto	102·3	5·3	18·3	5·2	A, B, C	Ditto
Rainy season (15th June—14th August)	116·3	3·4	9·9	2·9	2 and 10	Alternate daily
Autumn (15th August—14th October)	141·7	6·8	9·9	4·8	2 and 10	Ditto
Winter (15th October—14th February)	192·4	14·7	8·3	7·6	2 and 10	Ditto
Ditto	142·3	11·4	4·8	8·0	3 and 4, 5 and 6, 9 and 11	Ditto Third daily
Spring (15th October—14th February)	188·7	16·8	12·6	8·9	2 and 10	Alternate daily
Ditto	203·3	9·3	32·8	4·6	..	
Ditto	163·4	14·9	8·7	9·1	3 and 4, 5 and 6, 9 and 11	Ditto Third daily

From the foregoing statement it would appear that winter months are better producers of latex and rubber than the summer and in winter the spring shows the maximum yield. The rainy season gives a diluted latex with a minimum D. R. C. while the yield during summer and autumn months remains more or less uniform. For the formation of plugs, however, summer should be regarded as the best season. The third daily tapping is preferable to the alternate daily from the view points of better yield of rubber from latex and more rest to the plant and if a successful tapping programme is to be started it should be carried out during winter months which could be extended further, but the rainy season should always be excluded to avoid low yield and unnecessary labour.

Summer and winter monsoon. The effect of dilution on latex is more perceptible during summer monsoon than in the winter monsoon because in the latter case it consists of a couple of light showers during cold months which are not enough to change the normal course of the yield of latex, etc.

Wind. The velocity of wind and its direction do not appear to have any effect on the yield of latex and rubber.

Humidity. No generalizations can be put forward with regard to humidity in relation to the yield of latex, etc. During July, August and September, humidity variations of 100-39, 91-70, 98-50 (monthly averages—77, 82·9 and 84·9) respectively were observed and the latex had a poor rubber content (3·89, 3·23, 3·54 respectively), while in January, February and March there were the same fluctuations of humidity 100-54. 100-48, and 91-33 (monthly average of 77·9, 72·1 and 63·6 respectively), but the latex had a fairly high D. R. C. (8·15, 8·24, 8·41 respectively). It may be said, however, that humidity ranging between 30-60 during winter months along with low temperatures, exercises a certain effect on the production of latex in the plant while a still low humidity of summer months is helpful in the formation and drying of plugs.

Temperature. In Table II are given the average maximum temperatures for the months and the yields of latex, etc. The results show that during summer as the temperature increases the D. R. C. decreases and with a decrease of temperature especially during winter months there is a gradual increase of D. R. C. Thus high temperature decreases the formation of rubber in latex while a fall in temperatures raises it. On the other hand, the yield of rubber from plugs increases with an increase in temperature and decreases as it falls. On account of these reasons an equal quantity of rubber (rubber from latex and rubber from plugs) is produced both in the winter and in summer. If winter favours the tapping programme the summer equally advocates the collection of plugs.

Periods of defoliation and refoliation, flowering and fruiting. In general, defoliation starts towards the second or third week of January and is practically complete by the end of February. Soon after defoliation or almost simultaneously with it, small pinkish leaves and sprouts make their appearance and thereafter the growth is fairly rapid. It may incidentally be mentioned that at Okhla plantations of the bushes towards the canal bank started defoliotions and refoliations later than those away from it and in the Botanical Division of this Institute it was observed that plants in a plot which had received considerable manuring and had, in consequence, put up a more luxuriant growth defoliated much later and less severely than those in the other plots where the plants were poor in growth owing to a lesser degree of manuring. By the middle of April, the plants started flowering, but this flush did not result in setting up of follicles Next flowering commenced during October and November and this time follicles did set which attained maturity by middle of March. The results of Table I show that the yield of latex and rubber, etc. is much more during the winter months than in the summer and goes on increasing with the commencement of winter till the close of the spring (15th October-14th April) and declines thereafter. Thus the periods of defoliation and refoliation, flowering and fruiting appear to have effect on the yield of latex, etc.

Yield of latex, rubber and plugs per acre per annum. The statement given in Table III is indicative of the yield of latex and rubber per acre per annum for alternate and third daily tappings. The total rubber obtained from the two systems is 138·9 and 113·3 lb. respectively (from latex alone 69·9 and 69·1 lb. respectively) for 10,000 bushes each with 25 tapable branches. The number of shoots vary according to the size and age of the plant, but 25 appears to be a reasonable average number. In one year old plants, however, 6-10 shoots will be available for tapping and the yield

should not be expected to exceed one quarter of that given above per acre per annum. The present investigation includes observations for one year and is indicative as to the probable variations in the yield of latex and rubber. No final conclusion can be drawn at this stage about the yield of rubber per acre and the reaction of the plant with regard to tapping and to decide this, it is necessary to have at least five years data of the various tapping systems in different climatic conditions and in different localities of India. In view of the present observations about the yield of rubber from *Cryptostegia* the conclusion arrived at and reported earlier [1943] appears to be misleading.

TABLE II

Average maximum temperature and the yield

Month	Average max. temp.	Average humidity	In gm. on 1,000 shoots			D.R.C.	Name of block	System of tapping
			Latex	Rubber	Plugs			
22nd April to 30th April, 1943.	87·7	33·3	93·5	7·2	11·8	8·0	1 and 12	Mixed
May 1943	105·6	24·4	272·5	11·5	27·5	4·2	1 and 12	Ditto
June 1943	102·6	45·4	175·1	6·5	19·1	3·8	1 and 12	Ditto
July 1st—18th.	..	..	139·8	3·3	13·5	3·2	1 and 12	Ditto
July 21st—31st	93·9	77·0	109·7	2·9	7·4	3·2	2 and 10	Alternate daily
August	90·0	82·9	256·6	7·8	18·6	3·5	2 and 10	Ditto
September	92·8	84·5	285·2	13·4	20·2	5·2	2 and 10	Ditto
October	94·0	44·0	328·2	19·1	20·2	6·4	2 and 10	Ditto
November	85·7	44·1	306·1	30·5	17·3	6·9	2 and 10	Ditto
November	85·7	44·1	300·1	22·9	8·3	7·9	3 and 4, 5 and 6, 9 and 11	Third daily
December	77·3	62·8	372·1	29·1	10·1	8·2	2 and 10	Alternate daily
December	77·3	62·8	461·1	26·9	18·1	8·7	3 and 4, 5 and 6, 9 and 11	Third daily
January	68·7	77·8	462·9	37·9	16·0	8·2	2 and 10	Alternate daily
January	68·7	77·8	526·2	42·9	18·8	8·6	3 and 4, 5 and 6, 9 and 11	Third daily
February	74·4	72·1	437·7	35·9	22·0	8·4	2 and 10	Alternate daily
February	74·4	72·1	526·2	42·9	18·8	8·6	3 and 4, 5 and 6, 9 and 11	Third daily
March	80·3	63·6	347·6	34·7	24·3	10·4	2 and 10	Alternate daily
March	80·3	63·6	499·4	48·9	24·9	10·7	3 and 4, 5 and 6, 9 and 11	Third daily
April	94·8	46·9	358·7	30·3	35·7	9·2	2 and 10	Alternate daily
April	94·8	46·9	439·9	37·5	32·4	8·8	3 and 4, 5 and 6, 9 and 11	Third daily
May	108	27·0	511·6	30·0	27·4	6·1	2 and 10	Alternate daily
May	108	27·0	641·0	41·8	33·1	6·6	3 and 4, 5 and 6, 9 and 11	Third daily

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TABLE III

Yield of latex, rubber and plugs per acre

Period	Alternate daily			Third daily		
	Latex	Rubber	Plug	Latex	Rubber	Plug
		(In gm.)			(In gm.)	
Average yield for 1 month for 1,000 plants with 1 tapable shoot during summer	128·4	5·61	11·3	123·9	8·30	7·07
Yield for six months for 1,000 plants with 1 tapable shoot during summer	770·4	33·66	67·8	743·4	49·8	42·42
Yield for six months for 10,000 plants with 1 tapable shoot during summer	770·4	336·60	678·0	7434	498	424·20
Yield for six months of 10,000 plants with 25 tapable shoots during summer per acre	192600	8415	1695	185850	12450	10605
Yield of latex, rubber and plugs for six months during summer (in lb.)	424·6	18·5	37·3	409·7	27·4	23·3
Total yield of latex and rubber for six months per acre (in lb.)	424·6	55·8	409·7	50.7	..	..
Average yield for 1 month for 1,000 plants with 1 tapable shoot during winter	191·2	15·4	9·75	149·4	12·6	6·2
Yield for six months for 1,000 plants with 1 tapable shoot during winter	1147·2	92·4	58·50	896·4	75·6	37·2
Yield for six months for 10,000 plants with 1 tapable shoot during winter	11472	924	585	8964	756	372
Yield for six months for 10,000 plants with 25 tapable shoot during winter per acre	286800 or 632·27	23100 or 50·9	14625 or 32·24	224100 or 494·04	18900 or 41·66	9300 or in lb. 20·50
Total yield of latex, rubber and plugs for six months per acre per annum (in lb.)	632·27	69·4	69·5	903·74	69·1	43·8
Total yield of latex and rubber per acre per annum (in lb.)	1056·9	138·9	903·7	..	..	113·3
Average yield of latex and rubber from the two systems (in lb.)	980·3	126·1	..	..	..	..

Cost of production of rubber. If it is assumed that one man can collect one pound of latex in a day and gets for his daily wages annas twelve only then the total expenditure for the collection of 980 lb. latex would amount to Rs. 735 which would give a return of 126·1 lb. of rubber. This would mean a cost of Rs. 5-8 per lb. (8 shillings 6 pence when Rs. 13 are equivalent to £1). But according to pre-war wages the cost would be reduced to one third, i.e. it would come to Rs. 1-13 or 3 shillings per lb. This amount does not include any expenditure required for raising and maintaining *Cryptostegia* bushes and for coagulation of latex. This cost per pound when compared with that of *Hevea* rubber would appear to be exhorbitant and unless the yield of latex and rubber of *Cryptostegia grandiflora* is raised by systematic and scientific cultural investigations *Cryptostegia* may not be able to compete with *Hevea* as a normal source of vegetable rubber.

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PHYSICAL AND CHEMICAL PROPERTIES OF INDIAN HONEY

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HONEY is defined as the nectar and saccharine exudation of plants gathered, modified and stored in the comb of the honey bees. Besides water, the essential constituents of honey are dextrose, levulose and sucrose in small amounts together with lesser quantities of mineral matter, porteins, wax, pollen, and sometimes mannitol and dextrins, and nearly always appreciable amounts of various organic acids. The flavour of honey varies considerably according to its source. According to western standards genuine honey should contain not more than 25 per cent of water, 0·25 per cent of ash, and 8 per cent of sucrose. Its specific gravity should not be less than 1·412 and its weight not less than 11 lb. 12 oz. per standard gallon of 231 cubic inches at 68°F. It should contain dextrose and levulose in about equal proportions and be lævorotatory. Honey of coniferous origin, however, gives genuine dextrorotatory samples.

In India honey is mostly used for medicinal purposes and although collected under the most natural conditions, scientific and hygienic methods are not often employed for the purpose. Nor apiculture as a profitable adjunct to general agriculture and horticulture is extensively attended to. With the prospect of honey being used as a table-food, it is now, however, receiving greater attention from the Government, and honey may soon prove an important commodity in the commercial channels of trade in this country. In consequence, it is essential to decide upon a limit of different constituents, so that a suitable standard may be maintained for the composition of honey sold in the market. With this end in view, the present investigation was undertaken.

Studies by different workers [Browne, 1908 ; Daji and Kibe, 1940 ; Eckert and Allinger, 1939 ; Fraps, 1921 ; Giri, 1938 ; Neufeld, 1907 ; and Schuette and Remy, 1932] have shown that there is a good deal of variation in the physical and chemical properties of honey which will be evident on a reference to the data in Table I, collated from the work of different investigators both in India and

TABLE I

Average composition of Indian and foreign honeys

Percentage of constituents	Neufeld (1907)	Browne (1908)	Eckert and Allinger (1939)	Giri (1938)	Daji and Kibe (1940)	Das and Bose (1946)	
	European honeys	Average of 100 U.S.A. honey samples	Californian honeys	Average of 12 Coorg (Indian) honey samples	Average of 6 Indian honey samples	Average of 61 Indian honey samples	Average of 6 foreign honey samples
Moisture	.. (8·30-33·59)	17·59 (12·42-26·88)	16·50 ..	19·16 (16·20-22·14)	20·10 (15·88-24·22)	19·19 (14·17-28·67)	15·22 (14·31-16·39)
Specific gravity at 15°C.	..	..	..	..	..	1·404 (1·304-1·441)	1·427 (1·417-1·433)
Ash	.. (0·02-0·68)	0·23 (0·03-0·90)	0·21 (0·02-1·14)	0·10 (0·04-0·46)	0·58 (0·21-1·06)	0·29 (0·03-1·21)	0·11 (0·06-0·16)
Acidity as percentage of formic acid.	.. (0·03-0·21)	0·09 (0·04-0·25)	0·16 (0·07-0·45)	0·11 (0·06-0·29)	0·21 (0·13-0·30)	0·10 (0·05-0·32)	0·11 (0·07-0·15)
Reducing sugars	.. (49·59-93·96)	70·59 (59·61-79·86)	77·53 ..	74·98 (72·70-78·70)	65·21 (59·95-71·45)	70·78 (63·39-76·33)	71·37 (70·44-73·88)
Sucrose	.. (0·10-10·12)	1·98 (0-10·01)	2·53 ..	1·10 (0·29-1·04)	1·89 (0·37-3·95)	1·66 (0-5·07)	0·61 (0-1·42)
Levulose	..	40·50 ..	40·41 ..	39·30 (36·80-40·50)	36·98 (30·03-44·07)	37·95 (32·75-42·47)	36·58 (34·34-40·76)
Dextrose	..	34·02 ..	34·54 ..	35·68 (34·2-39·2)	28·23 (22·92-34·20)	32·82 (25·14-37·99)	34·74 (29·94-39·04)
Levulose/Dextrose	.. ..	1·19 ..	1·17 ..	1·10 (1·00-1·18)	1·35 (0·89-1·92)	1·16 (0·89-1·54)	1·07 (0·88-1·39)
Dextrin	.. (0·99-9·70)	2·09 ..	.. ..	.. ..	3·13 (0-6·54)	.. ..	.. ..

N.B.—The figures in brackets indicates the range of percentage variation of different constituents of honey

* Appointed at this Institute for the work with the funds provided by the Agricultural Marketing Adviser to the Government of India

abroad. The data obtained by the present authors with Indian and foreign honeys and discussed later in this paper are also given for comparison.

Thus, the setting up of standards for pure honey on a well-defined basis of different component is rather difficult. A reasonable limit may, however, be fixed up for practical purposes. In order therefore to find out such limits for the important components of Indian honey it was considered necessary to collect samples of genuine honey from all over India at different seasons for examination.

The samples of honey analysed. Sixty-seven samples of honey* were analysed for the present inquiry. Of these, 61 samples were obtained from such diverse places in India as Jammu and Kashmir, the North-West Frontier Province, Punjab, Delhi, the United Provinces, the Central Provinces, Bombay, Coorg, Madras, Mysore, and Assam. The samples were collected at different seasons from 1940 to 1943. Most of the samples were either extracted or squeezed honey and sealed in tins or glass jars. A few samples which were received with honey-comb were squeezed out by means of linen before they were submitted to analysis.

Six samples of foreign honey from the United States, Australia, New Zealand, and England as sold in the local market were also obtained for comparison with the Indian samples.

Experimental

The following components of honey were determined, for which the methods of analysis followed were those of A.O.A.C. [1940]. For easy reference they are briefly described below :

Colour. The tint of honey samples was compared in a one-inch cell of the Lovibond Tintometer with the coloured glass slide obtained from the British Bee Keepers' Association. The samples which compared more or less with the light-coloured side of the glass slide were termed 'Light Amber' and those which compared with the dark side were termed 'Deep Amber'. Intermediate tint was noted as 'Amber'. Some samples were lighter than the light-coloured side of the glass slide and were termed 'Extra Light Amber', whereas those which were darker than the deeper shade of the slide were termed 'Dark'.

Flavour. It is rather difficult to describe or measure the flavour of honey adequately, because of the variation in the preferences of different individuals. The samples which gave characteristic flavour of honey were termed 'Aromatic', while those which had cooked or charred smell, were termed 'Smoky' or 'Charred'. The samples which had no such smell as above were described as having 'Nil' flavour.

Besides colour and flavour granulation was also noted.

Diastatic activity. Ten cubic centimeters of honey solution (1 : 2) mixed with 1 c.c. of 1 per cent starch solution were digested at 45°C. for an hour. The solution giving olive green or brown coloration with iodine solution indicated positive diastatic activity, whereas blue colour meant negative diastatic activity.

Fiehe's Test. Ten cubic centimeters of honey solution (1 : 1) were extracted with 5 c.c. of sulphuric ether. Of the clear ether extract 2 c.c. were treated with a large drop of a recently prepared 1 per cent resorcinol solution in hydrochloric acid (sp. gr. 1·18 to 1·19). No coloration of even yellow to salmon shades indicated the absence of commercial invert sugar, whereas a cherry-red colour appearing within a minute indicated the presence of commercial sugar. It has been reported that in the manufacture of invert sugar commercially, the invert sugar produced is contaminated with a small amount of furfurol or its derivatives. The detection of these substances forms the basis of this test for the presence of commercial invert sugar in honey.

Moisture. This was determined by drying a known weight of the sample at 70°C. under vacuum to a constant weight.

Specific gravity at 15°C. This was determined by means of a specific gravity bottle fitted with a theromometer.

Acidity. A known weight of honey after diluting with sufficient water was titrated with N/10 NaOH solution, using phenolphthalein as indicator.

Total reducing sugars. These were estimated volumetrically using Soxhlet's modification of Fehling's solution.

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* These samples were collected through the Agricultural Marketing Adviser to Government of India to whom our thanks are due

Sucrose. This was calculated from the reducing sugars before and after inversion.

Levulose. It was determined from constant polarimetric readings at 20°C. and 87°C.

Dextrose. The amount of dextrose was obtained by subtracting the amount of levulose from that of total reducing sugar before inversion.

Ash. A known weight of honey was ignited in a weighed platinum basin at a temperature not above dull redness until white ash was obtained.

Presentation of results

The maximum and minimum as well as the mean values of the various constituents of honey collected from the different regions of India and abroad are shown in Table II. From regions like Delhi, the Central Provinces, Bombay, Assam, and the North-West Frontier Province the number of samples were rather small for the purpose of grade specifications.

Discussion of results

Colour. The colour of honey ranged from extra light amber to very dark and could be observed only in a general way in the absence of P fund colour grader (*U.S. Dept. Agri. Cir.* No. 24, 1933). It is well known that the colour of honey darkens on storage. In spite of long storage, however, certain samples maintained excellent colour, whereas others turned deep amber, or very dark. There was apparently no correlation between total ash content and colour.

It is probable that salts such as those of iron, copper, and manganese may account for the shades of colour. In fact, it was observed that the honey samples having deep colour always yielded either brownish or greenish ash containing appreciable amounts of iron, copper, and manganese, whereas the ashes obtained from light-coloured honey samples were always snow-white and had comparatively little of these elements. This is supported by the observations of Scheutte and Remy [1932], Giri [1938], and Daji and Kibe [1940] who have shown that there is a relationship between the degree of pigmentation and the quantity of mineral matter, notably manganse and copper, present in honey.

Flavour. The exact nature of the substances causing flavour is not fully understood. The flavour of the majority of samples was typical of honey. In some cases, the flavour was not aromatic. It is very likely that the smell of flowers from which the nectar is collected has some influence on flavour in honey, but when the nectar is collected from various kinds of flowers, flavour may be an integration of these aroma.

Diastatic activity. Honey, if not heated to a temperature more than 50°C., exhibits diastatic activity. Here, out of 67 samples, 55 possessed this property and 12 samples failed to show this, the reason for which is not clearly understood.

Fiehe's Test. No samples gave positive reaction with Fiehe's reagent, indicating the absence of commercial invert sugar in them.

Moisture. The moisture in the Indian honey samples analysed ranged from 14·17 to 26·67 per cent and the average of all the Indian samples came to 19·19 per cent ; 24 out of 61 Indian samples contained more than 20 per cent of moisture.

Well-matured honey from capped combs generally contains about 16 per cent of moisture. If it is, however, ill-matured or exposed to humid weather, the moisture content may go up. On the contrary, if the place is dry, the moisture content may go down as well. As for instance, the average of three honey samples from Delhi which is a dry place, was 14·39 per cent, none exceeding 14·53, whereas the average of three honey samples from Assam which is a wet area, was 27·12 per cent, none falling below 25·09 per cent.

Honey, if allowed to contain more than 20 per cent of moisture, suffers from a serious drawback. It is then susceptible to fermentation by sugar-tolerant yeasts and bacteria. Utmost care must, therefore, be taken, while gathering honey, to guard against its undue exposure to air, especially in humid regions.

TABLE II

The minimum and maximum as well as mean values of different components of honey samples from different regions of India and other countries

Place	No. of samples analysed	Percentage of moisture	Specific gravity at 15°C.	Percentage of ash	Acidity as percentage of formic acid	Percentage of total reducing sugars	Percentage of sucrose	Percentage of levulose	Percentage of dextrose	Levulose : Dextrose Ratio
Jammu and Kashmir	7	18·03 (15·89-20·63)	1·421 (1·410-1·431)	0·13 (0·07-0·29)	0·08 (0·05-0·13)	72·42 (71·70-73·01)	0·96 (0·00-4·05)	38·47 (36·53-40·51)	33·92 (31·86-37·29)	1·14 (0·98-1·29)
N.W.F.P.	1	17·17	1·421	0·31	0·05	73·28	1·62	40·19	33·09	1·21
Punjab	7	17·85 (14·25-23·85)	1·414 (1·387-1·432)	0·20 (0·03-0·47)	0·09 (0·05-0·13)	69·81 (67·30-73·28)	2·51 (0·00-4·51)	36·08 (33·69-37·91)	33·73 (30·86-37·99)	1·09 (0·89-1·26)
Delhi	3	14·39 (14·17-14·53)	1·437 (1·435-1·441)	0·44 (0·22-0·58)	0·12 (0·09-0·14)	73·89 (72·68-76·33)	3·13 (2·43-3·55)	37·67 (36·42-39·57)	36·28 (35·83-36·76)	1·04 (1·00-1·08)
U.P.	10	18·41 (14·51-21·97)	1·414 (1·401-1·434)	0·64 (0·08-1·03)	0·11 (0·07-0·15)	69·17 (66·28-71·70)	1·31 (0·00-2·80)	37·39 (33·44-41·60)	31·77 (27·99-35·27)	1·18 (0·95-1·44)
C.P.	2	15·29 (14·29-16·29)	1·428 (1·419-1·436)	0·31 (0·24-0·38)	0·12 (0·09-0·14)	70·52 (69·28-71·75)	2·66 (2·25-3·06)	38·43 (37·11-39·75)	32·09 (32·00-32·17)	1·20 (1·15-1·24)
Bombay	2	19·09 (18·92-19·25)	1·414 (1·410-1·417)	0·27 (0·24-0·29)	0·07 (0·06-0·08)	71·65 (71·08-72·21)	1·30 (1·18-1·42)	39·15 (39·07-39·23)	32·50 (32·01-32·98)	1·20 (1·18-1·22)
Coorg	8	21·37 (20·16-24·14)	1·380 (1·352-1·399)	0·14 (0·05-0·21)	0·10 (0·06-0·14)	70·90 (68·23-74·10)	0·46 (0·00-1·43)	38·58 (36·43-41·87)	32·19 (27·29-34·86)	1·21 (1·09-1·53)
Madras	12	19·95 (16·63-26·88)	1·400 (1·354-1·417)	0·43 (0·21-1·21)	0·14 (0·05-0·32)	68·65 (63·89-74·96)	1·78 (0·26-5·07)	36·93 (32·75-41·44)	31·74 (25·14-36·54)	1·18 (0·95-1·54)
Mysore	6	21·49 (18·87-24·10)	1·396 (1·359-1·415)	0·13 (0·10-0·17)	0·11 (0·06-0·17)	70·96 (69·66-73·52)	1·51 (0·00-3·79)	39·26 (36·71-42·47)	31·67 (27·70-35·25)	1·23 (1·08-1·42)
Assam	3	27·12 (25·09-28·67)	1·323 (1·304-1·353)	0·14 (0·10-0·19)	0·12 (0·09-0·15)	67·32 (66·39-69·18)	1·04 (0·41-1·41)	35·34 (34·27-36·01)	31·99 (30·54-33·17)	1·10 (1·05-1·17)
All.Indian samples	61	19·19 (14·17-28·67)	1·404 (1·304-1·441)	0·29 (0·03-1·21)	0·10 (0·05-0·32)	70·78 (63·89-76·33)	1·66 (0·00-5·07)	37·95 (32·75-42·47)	32·82 (25·14-37·99)	1·16 (0·89-1·54)
Foreign	6	15·22 (14·31-16·39)	1·427 (1·417-1·433)	0·11 (0·06-0·16)	0·11 (0·07-0·15)	71·37 (70·44-73·38)	0·61 (0·00-1·42)	36·58 (34·34-40·76)	34·74 (29·94-39·04)	1·07 (0·88-1·39)
American (Browne)	100	17·59 (12·42-26·88)	..	0·23 (0·03-0·90)	0·09 (0·04-0·25)	70·59 (59·61-79·86)	1·98 (0·00-10·01)	40·50	34·02	1·19
California (Eckert and Allinger)		16·50	..	0·21 (0·02-1·14)	0·16 (0·07-0·45)	77·53	2·53	40·41	34·54	1·17

N.B.—The figures in brackets indicate the minimum and maximum percentage variation of the different constituents of honey.

Honey with less tha 20 per cent of moisture is less inconvenient for table use, whereas samples with 20 to 25 per cent of moisture will spread quickly on bread. If 20 per cent is fixed as the upper limit of moisture, many honey samples will be left out. Therefore, 22 per cent seems to be convenient as the upper limit of moisture at present when scientific methods are rarely used for gathering honey.

Density. Density of all Indian honey samples varied from 1·304 to 1·441 and the average was 1·404.

Acidity. Acidity, expressed as formic acid, varied from 0·05 to 0·32 per cent and the average was 0·10.

Total reducing sugars. These varied widely from 63·89 to 76·33 per cent and the average worked out to be 70·78 per cent.

Levulose and dextrose. Levulose varied from 32·75 to 42·47 per cent and the mean was 37·95 per cent, whereas dextrose varied from 25·14 to 37·99 per cent and the mean was 32·82 per cent.

As in the case of reducing sugars, levulose : dextrose ratio varied from 0·89 to as high as 1·54 and the mean was 1·16. In most cases, however, the ratio was near about 1·1.

Granulation. An increase of the levulose content, expressed as levulose : dextrose ratio, tends to retard granulation, as has been noted by Browne [1908], and Eckert and Allinger [1939]. Thus levulose : dextrose ratio less than unity facilitates the formation of granulation in many cases. Out of the six cases with levulose : dextrose ratio less than 1·0, two samples showed no tendency to granulation, whereas some crystalline honey samples showed this ratio to be 1·0 and its near approximation. It should, however, be noted that the honey samples with high levulose : dextrose ratio were always in the liquid state. Samples from Coorg appeared to be particularly crystalline. Giri [1938] also made similar observations. Local conditions and flora, etc. may have some influence on granulation.

Sucrose. Sucrose varied from nil to 5·07 per cent and the mean was 1·66 per cent. The sucrose content of the samples analysed here is rather low, much lower than the limit of 8 per cent adopted for honeys in America. If 5 per cent is kept as the limit of sucrose, it is very likely to cover almost all Indian honeys.

Ash. Ash varied within a wide range from 0·03 to 1·21 per cent. Many of the samples exceeded the legal limit of 0·25 per cent allowed for honeys in America.

A few samples had very high ash contents. Of these, one sample was known to be gathered from honey dew. Taking most of the other samples, more or less free from contamination, it is proposed to fix 0·75 per cent as the upper limit of ash.

From Table II it is evident that the variation and the mean of different components of Indian honey samples compare favourably with those of the foreign samples with but a few slight exceptions in the case of samples collected from extremely dry and wet places.

From the results of analysis it is obvious that the fixation of grade specifications is not so easy for honey as in the case of the other agricultural produce [1937]. It is, however, possible to set up certain reasonable limits for some of the major components of honey as follows :

1. Colour should be within the range from extra light amber to deep amber.
2. Flavour should be characteristic of honey.
3. Honey should possess diastatic activity.
4. Honey should give negative reaction with Fiehe's reagents.
5. Honey should not contain more than 22 per cent of moisture.
6. Specific gravity at 15°C. should not be less than 1·350.
7. Honey should not contain more than 5 per cent of sucrose.
8. Honey should not have more than 0·75 per cent of ash.
9. Acidity of honey in terms of formic acid should not exceed 0·30 per cent.

The composition of honey has thus been shown to vary somewhat with the place of origin from which it has been collected. This may necessitate a certain amount of flexibility in the specification. For this purpose the values given in Table II may be referred to if the place of collection of honey is known.

Summary

Studies with 67 samples of honey, of which 61 samples were collected from different parts of India at different seasons, show that they differ considerably so far as their physical and chemical properties are concerned. Six samples were obtained from foreign countries.

The analysis of all the Indian samples indicated the following average components in percentages of the total: moisture 19·19; specific gravity at 15°C. 1·404; acidity in terms of formic acid 0·10; total reducing sugars 70·78; sucrose 1·66; levulose 37·95; dextrose 32·82; levulose : dextrose ratio 1·16; and ash 0·29.

The variation and the mean of different components of Indian honey compare favourably with those of the foreign samples, indicating the genuineness of the honey samples examined both here in India and abroad.

Attempts have been made to set up certain reasonable limits regarding the physical and chemical properties of honey samples on a regional as well as on all-India basis, thus suggesting grade specifications for 11 regions and India as a whole.

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TAMARIND-SEED PECTIN

By T. P. Ghose (Retired) and S. Krishna, Forest Research Institute, Dehra Dun

(Received for publication on 3 June 1946)

In a recent issue of this journal, Rajnarain and Dutt [1945] have stated that tamarind-seed kernels contain starch, and not pectin as reported by us [Ghose and Krishna, 1942]. The authors have drawn this conclusion from experiments which, to say the least, are elementary and do not stand any critical scrutiny. Since the seeds do not contain any starch, it is necessary to correct the wrong impression which their report might convey, particularly at a time like the present, when the country is threatened with a serious famine. The claim that the seeds contain starch to an extent of 65 per cent might mislead the public to using the kernels as food in place of cereals, especially when four million maunds of these are availale annually in India. It is true that in times of scarcity people in South India have resorted to eating the kernels, but there are no data to show what effect they had on the people, nor are we aware of any scientific investigations on the nutritional value of the seeds. In the absence of information on these aspects, it would be unwise to suggest that they offer 'a very important staple food comparing favourably in food value with wheat and maize'. To recommend the use of the pectin in the manufacture of jams and jellies is a different matter, since in these forms only small quantities (1/10 oz. of pectin will yield about 8 oz. of jelly) will be consumed.

The tamarind-seed product sets to a firm jelly in the presence of appropriate amounts of sugar and acid, and, in fact, it forms such firm jellies that a sample prepared in 1942 is still standing without much loss of strength. Though this fact has been brought to the notice of Dr Dutt (one of the authors) through private communication, he does not hesitate to make a mis-statement that the

jellies remain firm for a month only. Further, he brings this as a support to his contention that the tamarind-seed product is a starch. It is well known that starches, as a rule, do not form firm jellies under the same conditions as pectins do.

Though Rajnarain and Dutt's paper is dated 28 March, 1945, it has been made public in May 1946 through the August, 1945, issue of this journal. During this period several notes on the chemistry of tamarind-seed product have appeared from two sets of workers, besides ourselves [Ghose and Krishna, 1945 ; Nanji, Savur and Sreenivasan, 1945 ; Damodaran and Rangachari, 1945 ; Savur and Sreenivasan, 1946], and none of them has claimed the material to be a starch. They are all agreed that the pectin in the tamarind-seed kernel is not of the same class as that obtained from fruits, inasmuch as its constituent carbohydrate is not built on galacturonic-acid molecule. In physical properties, however, it shares with fruit pectins the most important property of setting into a firm gel with appropriate amounts of sugar and acid. It is on account of this property, which is the characteristic of all pectins irrespective of their chemical nature, that tamarind-seed product has been regarded as pectin [Rao and Krishna, 1946]. Investigations have shown that it is a carbohydrate which on hydrolysis with mineral acids yields xylose, glucose and galactose. It is surprizing that Rajnarain and Dutt have not even cared to identify the sugars formed as a result of the acid hydrolysis, and this simple experiment would have convinced them that the substance is after all not a starch.

It is unfortunate that the authors should have permitted the article to be printed without first checking up their findings in view of the several notes that have appeared during the interval between the date of dispatch and that of the publication. The data on which they have based their conclusion have been fully dealt with in our article which is already in press for May, 1946, issue of the *Journal of Scientific and Industrial Research* [Ghose, Krishna and Rao, 1946] and, hence, need no recapitulation here. Two points, however, require mention in this note. One concerns the colour developed by the tamarind-seed pectin with iodine on which Rajnarain and Dutt lay particular emphasis. It is common knowledge that, besides starch, other plant products are also stained blue or bluish with iodine. For example, agar-agar itself produces a bluish-violet colour with this reagent. A careful examination of the behaviour of the tamarind-seed product with iodine clearly reveals that the behaviour is not similar to that of starch. When treated with a drop of a dilute solution of iodine, starch gets blue-coloured ; under the same conditions the tamarind-seed product does not develop any specific colour. When N/10 iodine solution is added in drops to a dilute aqueous solution of the product (0·5 per cent), a greenish-yellow colour initially appears at the place of contact, but this changes to yellow on shaking. On further addition of iodine solution the following sequence of colour-changes takes place : orange, dirty brown, greenish brown and greenish blue. The blue colour, however, gets discharged on the addition of water. With concentrated solutions of the substance (1 per cent or over) a greenish-blue gel appears at the final stage. The greenish-blue gel also, on dilution with water, changes to an orange-yellow solution. Even the microscopic examination of an iodine-treated section of the seed kernel, as reported by Rajnarain and Dutt, is cursory and defective. Our investigations show that the thickened cell walls alone are stained blue, while the rest of the cell or its contents are not. The blue stain of the cell wall too is very easily washed off by the addition of a couple of drops of water. On the other hand, the blue colour developed by starch on the addition of iodine does not disappear under the same conditions. Further, the form of the thickenings of the cell wall cannot be mistaken for starch granules, even by a casual observer.

The second point relates to the occurrence of starch in the seeds and Rajnarain and Dutt have made a learned but an amusing statement that 'A seed without starch is like an animal without protein, definitely unthinkable............and there is no seed known which is free from starch'. It may be pointed out to them that (1) betel nut (*Areca catechu* Linn.), (2) date-palm seed (*Phœnix dactylifera* Linn.), (3) carob-bean seed (*Ceratonia siliqua* Linn.), and (4) S. American ivory nut (*Phytelephas macrocarpa* Riuz and Pav.) are some of the notable examples of seeds which do not contain starch.

It is thus clear that the assumptions and observations of Rajnarain and Dutt are defective and erroneous, and their conclusion baseless and misleading. It can be definitely stated that the tamarind seeds do not contain starch.

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REVIEW

A Note-Book of Tropical Agriculture

Compiled by R. Cecil Wood

(The Imperial College of Tropical Agriculture, Trinidad. pp. 136, 10*s*. 6*d*.)

THIS is a very important and useful book to agriculturists in general. Information on all conceivable aspects of agriculture has been compiled in the book; elaborate tables and illustrative diagrams enhance its value. The book opens with a consideration of weights and measures; there is in this chapter a very convenient table for converting one measure into another, e.g. pounds of water into cubic inches, cubic feet into gallons, etc. Then there is a chapter on surveying and mensuration followed by one on building and roads. Machinery and implements form the subject matter of another chapter and the problems of labour, soils and manures are successfully discussed in a practical manner. Various particulars regarding cereals, pulses, root crops, vegetables, oil seeds, fibres, condiments, sugar, rubbers, beverages, oil palms, fruits, etc. have been noted in the chapter entitled Crops. The next chapter is concerned with livestock management, feeding, breeding, rearing, etc. of different animals generally associated with agriculture including a list of medicinal substances and instruments which should always be at hand. The subject of dairy is appropriately dealt with after that of livestock management. A large number of diverse recipes has been listed which would indeed be considered helpful from many points of view. There is also a chapter devoted to statistics. The book concludes with a list of institutions of service to agriculturists in the tropics.

The book is a handy one, strongly bound to withstand rough handling and is to be regarded as a vade-macum to all agriculturists. The fact that a third edition, has been called forth testifies to the existence of a great demand for the book .—U.N.C.

FOURTH INTERNATIONAL CONGRESS FOR MICROBIOLOGY

NEWS has been received at the office of the Indian National Committee of the International Association of Microbiologists that the Fourth International Congress for Microbiology will be held at Copenhagen, Denmark, from July 20-26, 1947. The business of the Congress will be conducted through nine sections.

The office of the Fourth International Congress is located at Kommunehospitalet, Copenhagen, Denmark. The office of the Honorary Secretary, Indian National Committee (Dr A. C. Ukil), is located at the All India Institute of Hygiene and Public health, 110, Chittaranjan Avenue, Calcutta, from whom further information on the subject can be obtained.

For the information of those who will contribute papers, it is stated that a summary not exceeding 200 words should be in the hands of the General Secretary of the Congress at Copenhagen not later than the 1st January, 1947.

MGIPC—M—III-1-6—21-7-47—600.

ORIGINAL ARTICLES

STUDIES IN BUNDELKHAND SOILS OF THE UNITED PROVINCES

II. CHEMICAL COMPOSITION OF THE CLAY FRACTIONS IN RELATION TO THE PROCESS OF SOIL FORMATION

By R. R. Agarwal, M.Sc., D.Phil., Agricultural Chemist to Government, United Provinces, Cawnpore, and P. Mukerji, B.Sc. (Ag.), Assoc. I.A.R.I., Senior Research Assistant

(Received for publication on 4 September 1944)

IN a previous communication Mukerji and Agarwal [1943] reported the results of their investigations on the soil survey of a typical tract of land in the Bundelkhand region of the United Provinces. In that paper three genetic soil types were recognized and chemical, physico-chemical and mechanical data for each type were recorded along with the morphological characters. These soil types resemble somewhat, although superficially, the associated red and black soils described by Raychaudhuri and associates [1941 ; 1943] from other parts of India. It was, however, suggested, as a result of the discussion of the available data, that the soils of the Bundelkhand region might be classified under the great group of 'immature tropical tschernozems'. In the present paper the separated clay fractions from the profile samples of each soil type have been subjected to a thorough chemical analysis and the results obtained have furnished some very interesting data that throw considerable light on the chief pedogenic factors which are responsible for the formation of soils in that locality.

Literature

During recent years much attention has been paid to a study of the composition of the clay fraction, since it has been recognized that this is of considerable aid in characterizing soils in relation to their development. A large volume of published literature on the subject already exists mainly as a result of work done in Europe and America. Work in India on the pedological aspects of the clay composition of the different soil types has so far been extremely meagre. Reference may, however, be made to the work of Raychaudhuri and associates [1941 ; 1943] on red and lateritic soils of India, in which some investigations have been directed on the composition of the clay complex with a view to discover the nature of the processes of soil-formation leading to those typical soil types. Sen and collaborators [1941] studied certain physical properties as related to the clay composition and their silica-sesquioxide ratios for a number of red and lateritic soils of India.

Experimental

(i) *Methods of analysis*

After washing the soils free from carbonates and sulphates the clay fractions (below 0·002 mm.) were separated from the coarse sand free soils as in the ordinary International Pipette method using very dilute ammonia to assist dispersion according to the sedimentation procedure described by Nagelschmidt [1944]. The clay suspensions were siphoned off and flocculated by adding 5 c.c. of N-calcium chloride. The calcium saturated clay was then carefully washed through repeated decantations and finally collected, dried and preserved for subsequent analysis.

The clay was fused with sodium carbonate in a platinum dish and analysed as a silicate for the more important constituents, except calcium, using ordinary methods. Free silica was determined according to the tri-acid digestion method of Hardy and Follet-Smith [1931]. Free iron oxide was estimated by the modification of Truog's method [1936] as suggested by Drosdoff [1941]. Hardy's alizarin adsorption method to determine the free alumina content was employed as subsequently modified by Hardy and Rodrigues [1938].

There has been some controversy in regard to the results obtained for free alumina in soil colloids through the use of the alizarin adsorption method. However, recently the method of Hardy and Rodrigues has been tested and found to give values of free alumina in soil colloids which were in close agreement with those obtained by the modified method of Truog [1936]; Sulaiman and Mukerji. [1941]; Raychaudhuri, Sulaiman and Bhuiyan. [1943] and by the differential thermal method [Alexandar, Hendricks and Faust. [1941].

Base exchange capacity was determined by leaching with N-ammonium acetate solution and estimating the absorbed ammonia in the usual manner.

(ii) *Prifile descriptions*

Morphological descriptions of the three soil profiles are recorded in Table I.

TABLE I

The profile descriptions of the soils used in the investigation

Horizon	Depth	Description
		Type 1
A	0—5 in.	Bright reddish brown coarse-grained soil; loosely packed; very light textured; sparse growth of roots; non-calcareous and neutral in reaction.
B_1	5 in.—1 ft. 9 in. . .	Dark brown coarse-grained soil; slightly compact; loamy in texture; sparse growth of roots; non-calcareous and neutral in reaction.
B_2	1 ft. 9 in.—3 ft. 2 in. .	Dark brown soil mixed with big sized whitish stones imparting a whitish grey colour to the soil layer; non-calcareous and neutral in reaction.
C	3 ft. 2 in.—4 ft. . .	Undecomposed parent material loosely held; some whitish rock fragments which are very thinly distributed are calcareous.
		Type 2
A	0—10 in.	Yellowish brown soil; sandy-loam in texture; gritty in feel; single grained structure; friable and loosely packed; non-calcareous and neutral in reaction.
B_1	10 in.—2 ft. 3 in. . .	Brown soil with a faint reddish tinge; sandy-loam in texture; columnar in structure; roots visible; hard and compact towards the bottom; non-calcareous and neutral in reaction.
B_2	2 ft. 3 in.—3 ft. 9 in. .	Same as above but harder and loamy.
C	3 ft. 9 in.—4 ft. 10 in. .	Brownish grey soil interspersed throughout with *kankars* (dolomite); clayey loam in texture; highly calcareous; alkaline in reaction.
		Type 3
A_1	0—1 ft. 5 in. . . .	Black clay with a bluish tinge; cracks on wetting; very sticky in feel; impervious and indurated; non-calcareous and neutral in reaction.
A_2	1 ft. 5 in.—3 ft. . .	Same as above but contains whitish fragments of stones loosely held.
B_1	3 ft.—4 ft. . . .	Brownish black hard clay; very sticky and cemented; slightly calcareous and alkaline in reaction.
B_2	4 ft.—5 ft. . . .	Greyish brown hard clay; more calcareous.
C	5 ft.—5 ft. 10 in. . .	Compact ash coloured *bajri* (gravelly calcareous sand) highly calcareous and alkaline in reaction.

(iii) *Analytical data*

(*a*) *Type 1.* The results of analysis of the clay fractions separated from the soils of Type I profile mentioned above are tabulated in Table II,

Table II

Results of chemical analysis of clays (Type I)

Horizon	Depth	SiO_2 Total	SiO_2 Free	SiO_2 Comb	Al_2O_3 Total	Al_2O_3 Free	Al_2O_3 Comb	Fe_2O_3 Total	Fe_2O_3 Free	Fe_2O_3 Comb	MgO	K_2O	Loss of moisture above 105°	Ex. cap.
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	m.e. Per cent
A	0-5 in.	40·80	3·10	37·70	20·76	0·71	20·05	16·18	9·10	7·08	4·16	1·80	15·50	69·5
B_1	5in.—1 ft. 9 in.	40·70	3·92	36·78	19·26	0·52	18·74	17·68	9·60	8·08	4·73	2·48	14·65	68·0
B_2	1 ft. 9 in.—3 ft. 2 in.	42·97	3·65	39·32	20·96	1·23	19·73	12·98	5·70	7·28	5·69	0·95	15·85	75·5
C	3 ft. 2 in.—4 ft.	41·91	4·33	37·61	17·46	0·96	16·50	13·80	5·90	7·90	6·39	1·78	17·13	81·5

An examination of the data presented in Table II reveals clearly some of the more important developmental and weathering processes undergone in the soils belonging to Type I. Silica shows signs of disruption from the complex as weathering proceeds since it is less in the A and B_1 horizons as compared to B_2 or C horizons. Free silica is present to an extent of about 8-10 per cent of the total silica and it shows a tendency of leaching. The clay in A horizon contains the maximum amount of combined alumina and its content decreases with depth. Alumina shows a trend to be constant in the first three layers but becomes less in the C horizon, showing thereby that weathering tends to increase the alumina content of the clay complex. Iron oxide content is fairly high in the top layers and the free iron oxide is also similarly high in A and B_1 horizons. This probably confers on the soil its characteristic red colour. The accumulation of sesquioxides, both iron and alumina, in top layers and the increase of silica with the depth of the profile show the tendency for laterisation.

The clay of the C horizon seems to be rich in magnesia showing origin from ferro-magnesian minerals. It appears that weathering tends to deplete the clay complex of its magnesia for there is a gradual enrichment of the complex in magnesia as we go down in the profile. The complex is also rich in potash. Exchange capacity increases with depth which may be suggestive of the fact that the clay in the top layers being more sesquioxidic in character has lower exchange properties.

Derived data in regard to molecular ratios of some of the more important ingredients which are present in the silicate complex in a combined form are presented in Table III.

Table III

Derived data for clays (Type I)

Horizons	Depth	$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$	$\frac{SiO_2}{RO+R_2O}$	$\frac{SiO_2}{H_2O}$
A	0—5 in.	2·604	3·19	14·16	4·44	5·13	0·73
B_1	5 in.—1 ft. 9 in.	2·614	3·33	12·11	3·63	4·27	0·75
B_2	1 ft. 9 in.—3 ft. 2 in.	2·736	3·38	14·37	4·25	4·33	0·74
C	3 ft. 2 in.—4 ft.	2·995	3·87	12·66	3·27	3·53	0·66

The ratios of silica-alumina are not constant in all the depths but increase in the bottom layers showing that weathering tends to deplete the soil more of its silica than alumina. The silica-iron oxide ratios, on the other hand, indicate that more of iron is removed than silica but that the distribution fluctuates in alternate layers. The silica-sesquioxide ratios are remarkably constant in

the first two layers but the clay in C horizon has a slightly higher ratio. Silica total base ratios decrease more or less uniformly in the three horizons signifying that the potash and magnesian silicates are subjected to the greatest amount of disruption. Silica/water ratio is constant in A and B horizons but is slightly less in C horizon.

(*b*) *Type 2*. Table IV contains the results of analysis of the clay fractions isolated from the soils of Type 2 profile.

TABLE IV

Results of chemical analysis of clays (Type 2)

Horizon	Depth	SiO_2			Al_2O_3			Fe_2O_3			MgO	K_2O	Loss of moisture above 105°	Ex. cap.
		Total	Free	Comb	Total	Free	Comb	Total	Free	Comb				
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	m.e. Per cent
A	0—10 in.	41·75	3·76	37·99	27·35	5·33	22·02	7·00	5·50	1·50	2·58	1·91	16·30	76·0
B_1	10 in.—2 ft. 3 in.	40·35	4·05	36·30	28·70	8·80	19·90	9·60	6·00	3·60	3·26	1·23	13·80	63·0
B_2	2 ft. 3 in.—3 ft. 9 in.	41·25	5·55	35·70	27·12	7·48	19·64	8·00	7·70	0·30	3·30	1·58	15·30	68·0
C	3 ft. 9 in.—4 ft. 10 in.	40·98	4·50	36·48	21·28	0·77	20·51	11·60	7·40	4·20	4·27	0·78	17·00	67·0

In Type 2 the distribution of total silica is more or less uniform in all the layers but the content of free silica increases with depth. It seems that the free silica obtained from soil decomposition is washed down the profile as in the case of Type 1 profile. The combined silica content is more in the A horizon, and then decreases. The clays in A and B horizons contain more total alumina than the clay in C horizon. But there is greater amount of free alumina in this type than what was encountered in Type 1. The combined iron oxide in the silicate complex is remarkably low and the major portion of the iron oxide exists in the clay in an uncombined state suggesting that the iron silicates are the weakest minerals in the clays. The magnesia and potash contents of the clay seem to indicate the same trends as those found in Type 1 profile. The exchange capacity is highest in A horizon, becomes less in B_1 but increases again in B_2 and C horizons. It seems, as was observed in the case of Type 1 profile, that the exchange capacity of the clay follows to some extent the same order as the combined silica content.

Table V contains the derived data in regard to the molecular ratios of the more important chemical constituents so far as the quantities which exist in a combined form are concerned.

TABLE V

Derived data for clays (Type 2)

Horizon	Depth	$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$	$\frac{SiO_2}{RO+R_2O}$	$\frac{SiO_2}{H_2O}$
A	0—10 in.	2·803	2·925	67·28	23·00	7·501	0·70
B_1	10 in.—2 ft. 3 in.	2·773	3·093	26·79	8·66	6·433	0·79
B_2	2 ft. 3 in.—3 ft. 9 in.	3·053	3·083	31·62	10·26	6·023	0·69
C	3 ft. 9 in.—4 ft. 10 in.	2·668	3·016	23·09	7·65	5·315	0·64

The silica-alumina ratios are essentially constant in all the four layers. It is apparent that the accumulation of alumina in top layers observed in Table IV may be only relative. Silica-iron oxide ratios exhibit a very wide variation and show very marked decrease in the lower layers, showing that the soil forming processes are responsible for a considerable disruption of the ferruginous silicates in the soil complex. Silica total base ratios also show a similar breaking down of the silicates rich in potash and magnesia. With the exception of the B_1 horizon, the silica/water ratios are constant.

It is apparent that the processes leading to the formation of soil complex represented by Type 1 in which slight lateritic tendencies were observed have been somewhat stabilized in the formation of the complex represented by Type 2.

(*c*) *Type 3*. In Table VI is given the chemical analysis of the clays separated from the soils of the profile representative of Type 3.

TABLE VI

Chemical analysis of the clays (Type 3)

Horizon	Depth	SiO_2			Al_2O_3			Fe_2O_3			MgO	K_2O	Loss of moisture above 105°	Ex. cap.
		Total	Free	Comb	Total	Free	Comb	Total	Free	Comb				
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	m.e. -Per cent
A_1	0 –1 ft. 5 in.	45·88	1·70	44·18	24·93	0·47	24·46	7·20	6·10	1·11	2·54	1·45	16·72	79·0
A_2	1 ft. 5 in.—3 ft.	46·10	1·55	44·55	27·30	0·40	26·90	5·20	4·90	0·30	2·59	1·72	15·69	84·0
B_1	3 ft. –4 ft.	44·98	1·10	43·88	26·90	0·50	26·40	5·60	4·40	1·20	3·41	1·28	16·80	79·0
B_2	4 ft.—5 ft.	43·55	1·10	42·45	27·50	0·50	27·00	4·80	3·30	1·50	3·49	1·06	17·98	80·0
C	5 ft.—5 ft. 10 in.	42·50	1·10	41·40	26·70	0·31	26·39	3·40	3·30	0·10	3·08	1·03	21·29	68·0

Total silica is more in the two layers of the A horizon and the two layers of the B horizon are similarly more silicious than the C horizon. The distribution of silica shows that, unlike Type 1, weathering does not deplete the complex of its silica but makes it slightly richer in this ingredient. The amount of free silica in the profile is the least of that present in all the three types considered together and so is the quantity of free alumina. Moreover, free silica shows signs of accumulation in the top layers and free alumina is more in A and B horizons as compared to C. It appears that, as a result of the restricted drainage and lower topography of the soil type in question, the rising silica-rich ground-waters resilicate the complex liberated during the soil decomposition.

Combined alumina content is fairly constant in the profile. Free iron oxide as percentage of the total iron oxide has been found to be maximum in this profile. Magnesia and potash show almost similar trends as in the other two profiles. With the exception of A_2 layer the clay of which gave slightly higher exchange capacity the exchange capacity in A and B horizons is more or less uniform but is less in the C horizon. C-horizon is again poor in silica content and the base exchange capacity, thus, seems to follow the order of the silica content of the clay.

Table VII shows the derived data for the molecular ratios of the more important ingredients of the clays.

TABLE VII

Derived data for clays (Type 3)

Horizon	Depth	$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$	$\frac{SiO_2}{RO+R_2O}$	$\frac{SiO_2}{H_2O}$
A_1	0—1 ft. 5 in.	2·979	3·063	106·7	34·54	9·378	0·79
A_2	1 ft. 5 in.—3 ft.	2·789	2·805	394·5	140·60	8·984	0·85
B_1	3 ft.—4 ft.	2·739	2·819	97·16	34·47	7·382	0·78
B_2	4 ft.—5 ft.	2·574	2·667	75·19	28·21	7·221	0·71
C_1	5 ft.—5 ft. 10 in.	2·655	2·661	..	..	7·889	0·58

Silica-sesquioxide and silica-alumina ratios show that the soil-forming processes have brought about, on the whole, an increase in these ratios. Thus the clay from the C horizon is much less silicious than the clays from either B or A horizons. Silica-iron oxide ratios show that the soil complex is a much weathered material and similar evidence is obtained on a consideration of the silica total base ratios. Silica-iron oxide ratios further give an indication of relative accumulation of iron oxide in the B horizon.

Altogether, it seems indubitable that the soils represented by the profile described above are the highly weathered soils of the locality, as far as the iron oxide and total bases in the clay complex are concerned. However, the type is influenced locally by different hydrographical conditions as a result of lower topography and this brings about slight modifications in the soil-forming processes, specially in regard to the behaviour of silica which gets presumably fixed in the top layers.

DISCUSSION

The chemical analyses of the fractionated clays from the soils of Bundelkhand clearly show that the minerals to be attacked most by the process of weathering are those containing iron and magnesium. In Type 1 soils, which has a very coarse-grained texture and consequently free drainage, magnesia on decomposition is probably lost out of the solum but iron accumulates in the top layers presumably due to its lower solubility and immature character of the soil profile. In Type 2 soils magnesia is not entirely lost but is found along with lime deposited in the C horizon as *kankar* nodules in the form of dolomite ; but free iron oxide shows a tendency of slight eluviation to bottom layers. When the clays of Type 3 are taken into account we find that due to poor drainage magnesia had had no chance of deposition in the form of nodules but is found distributed in the C horizon as small sized *bajri* particles. Free iron in this case, too, is found accumulated in the top layers possibly as a result of precipitation due to the alkaline nature of the soil and restricted drainage conditions. It seems beyond doubt that the translocation of the products of weathering in the soil profile is influenced almost wholly by the topographical conditions of these profiles. Magnesia precipitates in the profile at various points depending on the movements of ground waters ; whereas, iron shows curiously enough three degrees of translocation in the three profiles from accumulation in top layers in the Type 1 soils to leaching in bottom layers in Type 2 and further accumulation in top layers in Type 3.

The three profiles described in the paper represent three successive stages in the development of the soils in the Bundelkhand region and it may be highly interesting to study in what manner the different ingredients in the soil complex are affected by this development. It is expected that such study would throw considerable light on the relative pedogenic forces which are responsible for the gradual alteration of the chemical nature of the soil complex as the weathering progresses. In such a study the horizons of the three successive genetic groups of soils have been arranged in a reverse order. For in all types the C horizon is the least weathered and A horizon the most weathered. Although, it may not be perfectly justified in the absence of relevant data to consider the C horizon of Type 2 as more weathered than the A horizon of Type 1 or the C horizon of Type 3 as more weathered

than the A horizon of Type 2, nevertheless, in arranging the clays in that order certain trends become evident from which valuable information can be secured regarding the manner in which chemical weathering progressed in the locality. The interpretation of the data further brings about differences due to the orographic or hydrographic variations in the soil types. For such a discussion the molecular ratios as given in Tables III, V and VII have been averaged for the layers of the same horizon in a type and the data obtained are presented below for the sake of comparison (Table VIII).

TABLE VIII

Effect of soil development on the molecular ratios

Soil type	Horizon	$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{RO+R_2O}$	$\frac{SiO_2}{H_2O}$	Ex. cap. m.e.
Type 1	C	2·995	3·870	12·66	3·53	0·66	81·5
	B	2·675	3·355	13·24	4·30	0·74	72·8
	A	2·604	3·190	14·16	5·13	0·73	69·5
Type 2	C	2·668	3·016	23·09	5·32	0·64	67·0
	B	2·913	3·088	29·20	6·23	0·74	65·5
	A	2·803	2·925	67·28	7·50	0·70	76·0
Type 3	C	2·655	2·661	..	7·89	0·58	68·0
	B	2·657	2·743	86·18	7·30	0·75	79·5
	A	2·889	2·934	250·60	9·18	0·82	81·5

Whereas in Type 1 the silica-sesquioxide ratios decrease regularly with advanced development, in Type 2 the maximum value is found in B horizon and in Type 3 ratios increase with development. The Type 1 soil being high-lying and open in texture allows free leaching of silica but sesquioxides are left behind at the seat of weathering ; but in Type 2 which lies on a flater topography accumulation of sesquioxides in top layers is not noticeable as maximum concentration of these ingredients is found in the B horizon. When we examine the development in the low-lying Type 3 soils an entirely different picture, viz. the resilication of the weathered products, is obtained. A far better idea of these important pedogenic processes may be secured by considering the silica-alumina ratios. It is evident that in Type 1 the ratios decrease rather rapidly from C to A horizons ; in Type 2 these ratios have become more or less stable but there is slight increase in the B horizon ; whereas, in Type 3 the ratios increase, although not to the same extent as they decreased in Type 1, from C to A horizons. These considerations point to the obvious conclusion that in the sesquioxides it is the alumina component which is more stable or takes part in the process of resilication, and this fact is further corroborated by an examination of the trend of variation in the silica-iron oxide ratios which have in general shown a regular increase with the process of soil development. The silica-base ratios likewise increase with advancing soil maturation showing that as the soil develops, more of the alkaline and alkaline-earth silicates are being attacked—a fact which has already been mentioned previously. With the exception of the A horizon of Type 2 the exchange capacity follows the trend of the variation in the silica-alumina ratios.

It may be of interest to reconsider in the light of the analytical data now obtained for the fractionated clay separates the evidences presented in Part I of this series regarding the classification of these soils into, 'tropical tschernozems'. Sigmond [1939] mentions that in the formation of tschernozems the bases released during the weathering of silicates are only slightly leached out. The easily soluble alkali salts are removed almost completely, but the less easily soluble salts of calcium and magnesium are only partly removed. The characteristic feature in the dynamics of such soil types observed for the Russian and American tschernozems has been found to be the

immobility of the sesquioxides both iron oxide and alumina. Moreover, the mineral composition of the whole profile has been reported to be practically the same. In the present case the results of analysis of the clay fractions do not in general point to the constant character of the mineral composition in the profile but the data obtained are very much similar to those obtained for other soils of the tschernozem type [Byers, Alexandar and Holmes, 1935]. The silica-alumina ratios of the clay complex show an essentially constant character but iron oxide seems to be affected differently in different soil types. This anomalous behaviour of iron oxide may be ascribed to the higher temperatures prevailing in the tropics which presumably exert greater disruptive action on the ferromagnesian minerals. With the exception of this notable variation, the soil clays in general show all the important characteristics of tschernozems and zonally these soils may perhaps be regarded as being typical of the 'tropical tschernozems'.

Minerals in clays have been indentified by X-ray diffraction methods, differential thermal methods and electron microscopic techniques but the chemical data can at best afford only an indication towards a recognition of the probable mineral composition of the clays. Thus Hendricks and Alexandar [1939] have described methods for the identification of clay minerals on the basis of the results of chemical analysis. The greater base exchange capacity (63-84 m.e. per 100 gm.) of all the clays in the three soil types of the Bundelkhand region, the higher combined iron and megnesium contents and the amount of water held after heating to 105°C. suggest that the major constituents of the clay minerals are of the montmorillonite type with probably varying proportions of hydrous micas.

Type 1 and Type 3 soils of the Bundelkhand region are respectively the typical red and black soils of the locality, which are more or less similar in morphological characters to the red and black soils found in Central or Southern India. It may be interesting to compare the data obtained for the Bundelkhand soil types with those obtained for similar associated types in other parts of the country as reported by Raychaudhuri and associates. Raychaudhuri, Sulaiman and Bhuiyan [1943] report that the black soil clays show a higher base exchange capacity than the red ones and that the base exchange capacity decreases down the profile of the black soil whereas with the red soil type it shows a maximum at an intermediate depth. In the case of Bundelkhand soil clays the average values for the base exchange capacity of the black soil type are only slightly higher than those for the red type for the A and B horizons only but not for the C horizon. The base exchange capacity decreases in the profile with depth in the case of the black soil but increases in the case of the red one. However, the fundamental difference between the base exchange capacity of the red and black soil clays isolated from the Coimbatore soils and those isolated from the Bundelkhand soils lies in their absolute values. In the former case the values ranged from 76·0-80·8 m.e. for the black type and 33·8-36·0 m.e. in the red one; but in the later case the values found are 69·5-81·5 m.e. and 68-81 m.e. for the red and black soils respectively. Among the other fundamental differences observed between the clays from the two soil regions may be mentioned the variations between their values for the silica-alumina and silica-sesquioxide ratios. Whereas, in the case of the Bundelkhand soils these ratios have been found to be slightly higher for the red type as against the black type, in the Coimbatore soils reverse was found to hold good. It appears on a joint consideration of the above facts that in the Coimbatore region the red soils are probably more weathered than the black ones, but in the Bundelkhand area the red soils show immaturity as compared to the black soils. The variations recorded above can, therefore, be ascribed to be due to the genetical differences in the soils of the two regions.

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Summary

1. The clay fractions from the profile samples of the three genetic soil types found in the Bundelkhand region have been thoroughly analysed and the data obtained have been discussed from the stand-point of soil genesis.

2. It has been found that iron oxide and magnesia containing minerals are subjected to greatest amount of weathering under the climatic conditions obtainable in the locality.

3. The processes of soil formation have been followed through the three successive stages of the development of the three profiles and it has been shown that as the weathering progresses more of the alkali and alkaline-earth silicates and ferruginous silicates decompose. The alumina in the complex, however, exhibits some stability.

4. The behaviour of potash, magnesia and iron oxide rendered free after decomposition has been found to be one of the chief pedogenic factors in the genesis and different morphological features of the soil types obtainable in the tract in question.

5. It has been suggested that in the low-lying soil Type 3 some resilication of the cleavage products may further take place mainly due to orographical and hydrographical conditions.

6. The data obtained for the three soil types have also been discussed in the light of the classification of these soils. It appears that these soils are zonally the 'tropical tschernozems' but in the immature Type 1 some evidence has been found of slight lateritic tendencies.

7. Evidence has been adduced to show that the minerals of the soil clays are essentially of the montmorillonite type.

8. The data obtained for the red and black soils of the Bundelkhand region have been compared with those obtained for the similar contrasted soils found near Coimbatore and reported by Raychaudhuri, Sulaiman and Bhuiyan [1943]. The variations observed have been ascribed to be due to differences in the genesis of the two types in the two soil regions.

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EXPERIMENTS ON GREEN MANURE CROP CULTURE AS A MEASURE OF CONTROL OF *A. CULICIFACIES* BREEDING IN PADDY FIELDS

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IN Pattukottai *taluk*, Tanjore District, South India, an irrigation system for rice cultivation was established, where there was no such canal system existing before, and immediately malaria broke out extensively, though not in an acute epidemic form. This *taluk* has an area of 677 square miles comprising 371 villages with a population of 302,194. But the peculiar feature was that malaria did not establish itself; the presumption by the Rockefeller Foundation workers that the area became endemic for malaria and would remain so became falsified, since malaria disappeared completely from the area except for a few cases here and there. That is, there had been a natural decline and disappearance of malaria. While attempting to discover the factors at work which produced the original epidemic, and how these factors became self-controlled, without the conscious intervention of man (no anti-malarial measures were adopted at all except in a field station where investigation was being carried out), it occurred to the senior author that the important factor must have been the output of *A. culicifacies*, that is progressive cultivation decreased the area available for continuous breeding of *A. culicifacies*. A paper on this thesis is being separately published. In the present paper the factor of rice fields alone in malariogenesis and a possible method of controlling it, are considered. An experimental study was carried out for this purpose.

This experimental study, reported below, was carried out as a part of the programme of a scheme of experimental control of rural malaria in Pattukottai *taluk*. The epidemiology of malaria in this area was discussed at some length by Russell, Rao, and Menon [1938] as a result of the investigations carried out by them in this area during the period extending from July, 1936, to March, 1938, under the auspices of the International Health Division of the Rockefeller Foundation and with the co-operation of the Madras Public Health Department.

To have a fuller understanding of the scope, objects and aims of the experimental study under discussion the following few salient epidemiological features of this area need stressing here :

(*a*) Malaria is a recent introduction to this area as a result of conditions brought about by the operation of Cauvery-Mettur new Irrigation Project.

(*b*) *A. culicifacies* which has been incriminated as the vector of this area, though ubiquitous in its breeding habits, has an intimate association with irrigation water.

(*c*) There is a marked ' malaria season ' coinciding with the irrigation season from July to January. The peak prevalence of the local vector was during the first half of this ' on-season ' for malaria.

(*d*) Paddy fields also breed anopheline larvæ, but the species found in a paddy field was governed by the condition or stage of cultivation.

3. According to the finding of the Rockefeller Foundation workers the order of importance of the various types of breeding places from the point of view of frequency of collection of *A. culicifacies* is as follows :

(1) Irrigation canals,
(2) Field channels,
(3) Hoof-marks, cart-tracks,
(4) Ditches,
(5) Seepage pools,
(6) Waste irrigation water,
(7) Borrow pits,
(8) Fallow fields,
(9) Rain water pools,
(10) Wells,
(11) Tanks,
(12) Growing rice fields.

The senior author took charge of the scheme in April, 1942, after investigation by the Rockefeller Foundation workers for five and a half years. Further investigation indicated that if at all there was an important source of *A. culicifacies* as things stood at the time, it was the paddy fields, and the immense importance of rice fields in the epidemiology of malaria in a permanently endemic area irrigated by canal systems (as contrasted with irrigation under wells and small tanks) was revealed.

A. culicifacies is said to be a poor vector and it becomes an important vector only because of its density of prevalence [Russell and Rao, 1942,1]. Assuming this hypothesis to be correct a particular kind of breeding place of this species must be of greater importance on account of its extent and length of period of suitability for breeding, particularly in relation to the transmission season, than other breeding places which are not of much significance in these respects. Apart from factors making a breeding place particularly suitable to *A. culicifacies* its output may be considered to be proportionate to the effective area available for breeding. *A. culicifacies* larvæ were collected generally within 6 in. of the margin of channels, from the whole-water-surface practically of small borrowpits and wells, within about three feet of margins of tanks, and the whole area of paddy fields. Also it was noticed that at any one time only about ⅓ of the total area of paddy fields in a village was found suitable for the breeding of *A. culicifacies*, the rest being in a state or stage of paddy growth in which no *A. culicifacies* breeding could be found; wet fallow-state, before ploughing is a very fruitful source of *A. culicifacies*. The actual area available for breeding in the different kinds of breeding places, was actually measured in six villages and it was found that paddy fields constituted about 86 per cent of effective breeding area. Under instructions from the senior author as Malaria Officer, Madras, this unit collected some preliminary data in this respect during 1940. The figures obtained during 1943 are furnished in Table I, showing the relative importance of the various types of *A. culicifacies* breeding places. The larvæ coefficient per visit for the different habitats was worked out as a result of routine observations during a period of one year in 19 villages.

TABLE I

Relative importance of A. culicifacies *breeding places*

Villages	Tanks	Wells	Pits	Main channels	Field channels *Kannis* and drains	Paddy fields
1. Mudalcheri	26500	1920	173300	23800	40200	6180000
2. Muthakurichi (Kandiankadu)	29300	810	4700	15300	2100	915000
3. Sendankadu (Surankadu)	11580	1320	14700	9260	12320	3120000
4. Sendakottai (Maliakadu)	930	3520	35950	10850	9100	3430000
5. Thuvaranmurichi (Keelakkadu)	31050	710	27940	10460	14100	3700000
6. Karambayam (Kathirikollai)	17100	1410	144960	9730	3500	7850000
Total of breeding area in sq. ft.	116460	9690	401550	79400	81320	25195000
Percentage of breeding areas to total breeding areas	0·45	0·04	1·55	0·31	0·31	97·34
Larvae coefficient per visit	0·40	3·20	1·90	7·60	8·50	0·50
Area × coefficient	46584	31008	762945	603440	691220	12597500
Percentage of area as reduced by coefficient	0·32	0·21	5·19	3·76	4·72	85·80

NOTE.—Larvae coefficient No. of *A. culicifacies* larvae per visit, time being constant.
Breeding areas calculated as follows:
(1) Tanks—peripheral length × 3 ft. width.
(2) Wells and pits—whole area.
(3) Main and branch channels of width not less than 8 ft. length of both edges × one foot.
(4) Field bothies, *kannis* and field drains—length of both edges × 4in. (Radius of dipper 3 in.).
(5) Fields—total wet ayyacut × 0·3273.

Even though the density of breeding of *A. culicifacies* below in paddy fields, the total output of the adult mosquito from this source must be great indeed in proportion to the enormous extent of the available breeding area. That being so, the control of *A. culicifacies* need be confined to only paddy fields, for the purpose of controlling malaria in a rice field area or country irrigated by extensive canals and where the vector species is only *A. culicifacies*.

A. culicifacies though occurring throughout the year showed marked seasonal trends. In June and July, i.e. immediately after the letting in of irrigation water into this area, a rapid rise in the output of adults and larvae occurs and is continued up to August and September with the peak prevalence in August. This rise commences when the relative humidity is low, an unfavourable factor. Other meteorological conditions such as temperature, saturation deficiency and rainfall also seem adverse at the period of the rise. And what is more strange is that when meteorological factors are favourable after September the prevalence of this mosquito drops down abruptly. No satisfactory explanation for this was forthcoming. Perhaps an explanation for this rather strange phenomenon is the availability of the most suitable breeding places (paddy fields in the early cultivation stages) to an enormous extent in the early part of the season and the tremendous output in them masking every other factor and the non-availiability of such breeding places in the latter part of the season, all the other breeding places remaining fairly constant in size. Russell and Rao [1942,2] had reported that from mid-August to mid-October the mortality rate of *A. culicifacies* imagines is about 50 per cent every two days. It is therefore apparent from this that the mortality during the preceding hot dry months must be greater still. To build up such a high and increasing populations in the face of high mortality during these months the breeding places and the output of *A. culicifacies* in them must necessarily be enormous. This should forcibly stress the importance of wet fallow rice fields during this period which outstrips all adverse factors. *A. culicifacies* breeds usually profusely in small grass-free pools. This kind of breeding places will be seen extensively in a wet-fallow field, and hence its importance in the output of *A. culicifacies*.

All the developed fields in this newly irrigated area are not brought under cultivation simultaneously during the irrigation season because of the poor economic condition of the ryots and due to various other reasons. Owing to lack of uniformity in agricultural practices it is very common to see large areas lying in a wet fallow condition for longer periods than necessary till August or September. The wet fallow conditions begin in June and after variations and increase in their area according to progress of cultivation practically completely disappear by end of September or middle of October. One of the reasons advanced for the absence of malaria in some of the old deltaic villages of Tanjore district is that the rice fields in the old delta remain wet fallow for very much shorter period prior to transplantation than in the Grand Anicut Canal area (Pattukottai *taluk*). Any method which abolishes or reduces the breeding of *A. culicifacies* in rice fields during the period of its peak prevalence should be of great importance in the control of malaria in this area. Three methods of malaria control were recommended for this area by the Rockefeller Foundation workers. They were tried in a small area on an experimental basis but it was found that if these methods were applied to the whole *taluk*, the cost would be prohibitive running to more than a crore of rupees perhaps. Moreover, they were found to be impracticable.

In the meanwhile it was considered that the growing of green manure crop would possibly help in controlling of breeding of *A. culicifacies* and hence act as a malaria control measure ultimately in this area. This is entirely a new method. Its rationale will be clear from the following discussion.

(*a*) It has been observed recently in the Cauvery-Mettur Project area that active breeding of *A. culicifacies* in rice fields continues with maximum density as the phases of cultural operations such as ploughing planting and growing stages take place until the rice plants are about a foot high after which the fields are no longer dangerous in this respect. It would appear likely that rice plants above a foot in height inhibit the oviposition of *A. culicifacies*. The decline of *A. culicifacies* adults commencing from October is also interesting in this area as it is not due to any adverse meteorological conditions (as a matter of fact meteorological conditions are more favourable after October) or reduction in the area of breeding places. It may perhaps be due to the disappearance of the particularly favourable breeding places to this species especially the wet fallow rice fields. By October end

very few fields, only a negligible proportion of the total cultivated area, are in existence in the wet fallow condition or the earlier stages of agricultural operations, majority of the fields being in the vegetative phase with crop over one foot high. All these are suggestive of the epidemiological importance of rice fields prior to the active vegetative phase and the need for controlling *A. culicifacies* breeding during this period.

(*b*) In his report No. 62 dated 4th March 1912 Ross had stated "during the rainy months of December and until the middle of January the larvae and nymph of *culicifacies* were found in every pool mingled in places with *rossi* but in the paddy land between Kathiavakkam Village and the canal, the larvae caught were either *fuliginosus* or *rossi*. By the middle of January, pools had begun to shrink and their edges became green with grass; from this time until the time of writing *Neocellia fowleri* and a species (not anopheline) identified as *Aedomyia squamipenna* replaced *culicifacies* and *rossi* in most grass edged pools though in the casurina plantation pits where grass does not grow *culicifacies* hold sway". In his preliminary report on Pattukottai area dated September 1936 the senior author had stated that "paddy fields breed anopheline larvae but the species found in a particular field was governed by the condition or stage of cultivation".

Considering together the observations made by Ross, the senior author of this article and Russell and Rao [1942,3] it would appear that the virtue of obstruction need not be considered peculiar to paddy of more than one foot high. Probably paddy crop of one foot and more in height acts not on account of its height but because of the thick foliage of paddy blades. The senior author knows very well the area referred to by Ross in 1912. The grass cannot be characterized as one foot high and more. It will be mostly less than this from about 3 to 6 in. It will be more correct to say that *A. culicifacies* prefers for oviposition grass free edges. And if further studies are made it may be possible to say that it is a question of vegetation free edges (emergent vegetation of sufficient thickness and height above water surface), and not necessarily paddy-free or grass-free edges. Large scale studies on this point are likely to be of great value as there is the possibility of devising suitable naturalistic methods of control of *A. culicifacies* as a result of such studies. It was argued that if during the wet fallow condition of the fields there is already a standing crop there to prevent oviposition by *A. culicifacies* the breeding of this mosquito in paddy fields would be controlled. And if this standing crop is useful to the agriculturists also then two purposes will be served.—

(i) Prevention of *A. culicifacies* breeding; and (ii) Utility to ryot.

A green manure crop was found to answer the requirements.

These observations led us to presume that a thick growth of a green manure crop in rice fields must certainly offer sufficient mechanical obstruction to keep *A. culicifacies* out of them and therefore experimental studies were planned.

(*c*) All the green manure crops that are used for agricultural purposes belong to the leguminous type and it is a well known fact that legumes fix in the soil the nitrogen of the atmosphere by certain bacterial action thereby increasing the nitrogenous contents of the soil. The soil in this new project area is reputed to be deficient in humus and nitrogenous contents. It is an accepted fact that many anopheline species particularly those concerned in the transmission of malaria avoid water, the nitrogenous content of which is high. Hence the possibility is that a well manured paddy field in due course of time may prevent *A. culicifacies* breeding. (The manurial problem in the Grand Anicut Canal area is said to be difficult if not acute as there is great scarcity of farm yard manure). In the case of fields with the green manure crop the manure plants are ploughed and puddled into the soil in the very first ploughing and during the whole period the fields are in this phase of ploughing and puddling, a high degree of organic pollution and contamination of the wet field take place so as to inhibit *A. culicifacies* breeding.

(*d*) It has been estimated by the Agriculture Department that the raising of green manure crop in rice fields increases the yield of paddy by at least 50 per cent in a soil newly brought under cultivation and by 10 to 25 per cent in old soil. This would certainly go a long way in bettering the economic condition of the ryots. It has already been mentioned that the generally poor economic condition of the ryots of this area had been the chief limiting factor in the rapid development of the new irrigation area both in regard to intensive and extensive cultivation which constitute probably by itself an

important method of irrigation-malaria control. That it is considered by some that improvement in the economic condition of a malaria-stricken community is helpful in malaria control needs no reiteration.

Experimental study

Two villages namely Veppangulam and Thallikottai on the Pattukottai-Mannargudi road were selected for the study in 1943. The manure crops tried were *kolingi*, *daincha* and sunnhemp. A complete belt of lands around each village was sown with the above crops. The total of 215 acres was under *kolingi*, 9½ acres under *daincha* and 82·69 acres under sunnhemp in the two villages. A brief description of the three plants and the time of their sowing, etc. is given below.

Kolingi (*Tephrosia purpurea*)

This is a wild growing herb with plenty of lateral branches and thick foliage. It grows to a height of about 2 to 3 ft. A thick growth of these plants is capable of affording effective shade as well as mechanical obstruction to the ovipositing female *A. culicifacies* mosquitoes in a way that any water stagnation in the field is completely hidden. These plants grow well only in comparatively dry soil and in their wild growth are often found abundantly only during the dry summer months. They wither under water-logged or wet conditions. When water stagnates for about a fortnight in the fields in which these plants have been grown they die out, but they produce conditions inhibitive to *A. culicifacies* breeding by organic pollution of the water by the rotting of fallen leaves and shoots. They are usually sown in rice fields when the previous paddy crop is nearing harvest, a week or ten days before the harvest, when there would be some water left in the field which would be useful for the germination of the seeds. By the time these seeds sprout out the harvest of the paddy would be over and the moisture that would be left in the soil of the harvested field would be sufficient to give a start for the young seedlings. No further watering is necessary. In the present experiments these were sown only a week before the harvest during the second week of January 1943. The one important advantage of this particular crop over the others is that if it is given a start by persistent sowing for two or three years it ultimately establishes itself without the need for subsequent sowing. This is due to the fact that a certain percentage of the seeds, that are ploughed into the soil, is capable of lying dormant in the soil for long periods, one year even ordinarily, and then sprouting when the soil becomes semi-moist. These plants are usually grown in fields which are not moist during summer and non-irrigation season and are of a sandy loamy nature. In the Grand Anicut Canal area fields which are moist or semi-moist during the non-irrigation dry season constitute only a very small percentage of the total paddy crop area. From our general observations it can be said that this plant can be tried as a green manure crop for at least 90 per cent of the developed ayyacut in the Grand Anicut Canal area the rest being in a marshy or damp condition, a condition unsuited to the growth of this plant.

Daincha (*Sesbania aculeata*)

This is a downy shrub which sometimes grows to a height of 6 to 8 ft. It gives off lateral branches only after it has grown up to a certain height and has a rapid growth. It is therefore grown only after the letting in of irrigation-water in June and will be useful for fields wherein agricultural operations commence by or after the middle of August or so and which are unsuitable for the growth of *kolingi* on account of the nature of the soil. During the early stages of its growth for a month or so it is not of much use from the point of providing either dense shade or mechanical obstruction to the required degree but since the ryot will take care that the field is not water-logged for fear of destruction of the plant this defect is not of much significance. As it advances in age a thick growth with plenty of lateral branches provide good mechanical obstruction.

Sunnhemp (*Crotalaria juncea*)

This is a plant which can be said to be neither a herb nor a shrub but is midway between them. It grows up to a height of 4 to 5 ft. It gives off only a few lateral branches at the tips just before the

flowering stage. The foliage is also moderate. It has to be sown after the letting in of irrigation water just as *daincha* with an initial wetting and ploughing. This seems to require a certain amount of moisture in the soil for its good growth but does not stand marshy or damp condition. It is a very short duration crop of say 40 or 45 days—this seems to be its only advantage. But since it does not give off lateral shoots or foliage and since it is subject to attacks of a pest, it was considered of not much practical value in control of *A. culicifacies* breeding and the results of observation on this plant are therefore omitted from the report.

These experiments were planned and relevant data collected in such a way as to determine chiefly the effects of green manure crop culture on *A. culicifacies* breeding in rice fields at the various stages of agricultural operations. No attempt was made to study the incidence of malaria in the villages around which green manure crops were grown as malaria in this Grand Anicut Canal area was at the time of starting these experiments found to be rapidly declining. Moreover, if a study of the incidence of malaria in relation to this method of control was made the scope and extent of the experiment must necessarily have been bigger. Such a large scale study was not necessary since the only point to be proved was whether green manure crop culture would control breeding of *A. culicifacies* in paddy fields or not and if it did control such breeding the legitimate inference can be that the malaria also will be controlled since rice fields constitute 86 per cent of the effective area for its breeding. Anopheline larvae were collected in the above fields. A total of about 2070 collections were made. Standardized method of larvae collection was uniformly adopted, each collection being for a constant period of five minutes.

As the wet condition of the fields varies week after week, larvae collections were made in as many fields as were in the wet condition and over a wide area. Further, these observations were carried out in a larger area under actual field conditions so that the data collected might give a clearer idea than the data gathered in a few selected experimental plots. The figures, viz. the total number of *A. culicifacies* identified from the collections and the percentage of *A. culicifacies* to the total larvae identified, furnished in Table II, give a clear and conclusive indication of the inhibitive effects of green manure crops on *A. culicifacies* breeding in rice fields. Collections in fields with dense growth of *kolingi* were negative for *A. culicifacies*, while in the fields with dense growth of *daincha* and moderate growth of *kolingi*, the percentage of *A. culicifacies* was less than 4 per cent. In this connection it must be mentioned that green manure crop culture is a new introduction to this area and particularly in the villages where they were tried by us. Owing to abnormal summer showers in 1943 and lack of sufficient co-operation from the ryots, the green manure crops were successfully raised to the desired effect only on a small portion of the total area under green manure crop. When once this practice is earnestly taken up by the ryots and is established firmly, dense growth of green manure crop can effectively be raised. In contrast to the percentage of *A. culicifacies* in the fields with green manure crop, the figures obtained in the control fields with no *kolingi* was as high as 13·7 per cent. Even fields with moderate growth of *kolingi* recorded only 3·2 per cent of *A. culicifacies* larvae which is less than 25 per cent of the figures for the control fields. Fields ploughed with the green manure crop also showed practically negative figures for *A. culicifacies* breeding and this inhibitive effect was noticeable even to the stage of paddy crop coming up to a height of one foot after transplantation. The percentage of *A. culicifacies* in the fields ploughed without green manure crop was also as high as 16·6 per cent. From the above statements it may be seen that the frequency of collection of *A. culicifacies* larvae was considerably greater in the control fields (wet fallow without green manure crop and wet fallow ploughed without green manure), than in the experimental fields (wet fields with green manure). In collections in which only one or two *A. culicifacies* larvae were recorded the possibility of their presence due to the larval drift from the field channels through which the fields have been watered should not be ruled out and must be borne in mind in studying the data furnished.

A 50 per cent reduction of *A. culicifacies* is all that is necessary to abolish effective transmission, since this species is a very poor vector in this area with an infection index of 0·1 per cent. It is generally so in non-epidemic areas. It is the density, that is larger output, that seems to be the important factor. Viewed in this way the effect produced by green manure crop culture on *A. culicifacies* output is more than satisfactory.

With a view to confirm the observations carried out in 1943, experimental studies were continued in this respect, during the irrigation and agricultural season of 1944 and 1945. In 1944 six villages were selected for observations. Only a few acres of land in each village were kept under green manure crop. Owing to complete failure of summer showers and the quality of seeds then available with poor germination rate, the crops raised were not to the desired effect. Observations were carried out (week by week) this year in selected plots till the paddy crop grew up to a height of one foot. A summary of the results of the observations is furnished in Table III. A few further observations on the lines of study in 1943 were made during 1945 also and a summary of the data collected is furnished in Table IV. It may be seen from these figures that the first year's observations have been amply confirmed.

TABLE II

Consolidated statement of larvae collections in rice fields during 1943

Habitat	Total No. of			Percentage of *A. culicifacies* larvae to the total identified
	Larvae collections	Anopheline larvae identified	*A. culicifacies* larvae identified	
Wet fallow field with thick growth of *kolingi* crop	42	334	..	..
Wet fallow field with moderate growth of *kolingi* crop	358	1982	64	3·2
Wet fallow field without *kolingi* crop (control)	591	2876	395	13·7
Wet fallow field ploughed with *kolingi* crop	315	2133	20	0·9
Wet fallow field ploughed without *kolingi* (control)	132	805	134	16·6
Wet fallow field with thick growth of *daincha* crop	67	414	16	3·86
Wet fallow field ploughed with *daincha* crop	46	30	..	..
Growing rice field with paddy crop of less than 1 foot height (*daincha* previously grown).	43	109		..
Growing rice field with paddy crop of less than 1 foot height (*kolingi* previously grown).	300	738	..	

TABLE III

Consolidated statement of larvae collections in rice fields during 1944

Habitat	Total No. of			Percentage of *A. culicifacies* larvae to the total identified
	Larvae collections	Anopheline larvae identified	*A. culicifacies* larvae identified	
Wet fallow field with thick growth of *kolingi* crop	55	663	6	0·9
Wet fallow field with poor growth of *kolingi* crop	56	812	39	4·8
Wet fallow field without *kolingi* (control)	54	867	64	7·4
Wet fallow field with thick growth of *kolingi* after ploughing	33	493	1	0·2
Wet fallow field with poor growth of *kolingi* after ploughing	23	393	11	2·8
Wet fallow field without *kolingi* after ploughing (control)	26	486	11	2·3

TABLE IV

Consolidated statement of larvae collections in rice fields during 1945

Habitat	Total No. of Larvae collections	Total No. of Anopheline larvae identified	Total No. of *A. culicifacies* larvae identified	Percentage of *A. culicifacies* larvae to the total identified
Wet fallow field with thick growth of *kolingi* crop	12	273	..	..
Wet fallow field with moderate growth of *kolingi* crop	2	170	..	..
Wet fallow field with thick growth of *daincha* crop	11	177	..	..
Wet fallow field ploughed with green manure crops	11	155	1	0·6
Growing rice field with paddy crop of less than 1 foot height previously grown with green manure crop	2	9	..	..
Wet fallow field without *kolingi* (control)	65	757	89	11·8

SUMMARY

Green manure crops do effectively create conditions in rice fields during the various stages of agricultural operations inhibitive to *A. culicifacies* breeding, the one or the other or a combination of factors enumerated in this paper coming into play during the peak months of *A. culicifacies* breeding in the Grand Anicut Canal area.

Kolingi seems to be the most suitable green manure crop to this area. In other places where similar problem obtains, the agricultural expert may suggest, in consultation with the malariologist, the most suitable manure crop for the local soil.

The growing of green manure crop solves also the manurial problem in the Grand Anicut Canal area where the soil is said to be poor and farm yard manure difficult to obtain.

Increased yield and the consequent betterment in the economic condition of the ryot.

The possibility of this method of malaria control proving an unique naturalistic method of control against *A. culicifacies* breeding in rice fields, particularly in deltaic and new irrigation area subjected to agricultural or irrigation malaria is indicated. There are many kinds of green manure crops and it may not be difficult to select a suitable one.

To foresee and prevent outbreaks of malaria in areas to be newly brought under canal irrigation (outbreaks like those which occurred in the Irwin Canal area in Mysore and Grand Anicut Canal area in Tanjore district), it may perhaps be enough that a scheme of extensive green manure culture properly designed and executed is put into operation, even before the first cultivation commences.

Malaria in India is mainly a rural problem and if careful investigations are made, the problem will more often be found associated with agriculture. Apart from the water-tidiness that must be practised in the distribution of water there is yet the question of the agricultural practice itself.

The method of green manure crop culture is strictly in imitation of nature The problem of rural malaria is so enormous and extensive that it will be the height of folly to think of the present-day methods which are usually costly. It is suggested that methods like green manure crop culture and others which can be brought under ' sanitated agriculture ' may be taken up for intensive study as an item in rural reconstruction and postwar reconstruction.

A scheme of green manure crop culture as a malaria control measure will not cost the Government anything at all except the money spent on propaganda which is ordinarily a legitimate expenditure of the Agriculture Department. The expenditure on green manure crop will finally become part of the ryots' agricultural budget and it will not be felt as an extraordinary expenditure at all. That is to say he himself will be establishing malaria control and it will cost him next to nothing to do this.

There are many new irrigation projects coming into existence shortly. It is suggesred that it will be worthwhile to investigate naturalistic methods of control and put into practice any useful ones in connection with these projects before it is too late.

The method of green manure crop culture establishes continuous control of breeding of *A. culicifacies* from the time water is let into a rice field, accidentally or intentionally, till the time when the height of paddy growth itself is sufficient to prevent oviposition. Malaria transmission will be abolished every year and the disease will finally die a natural death.

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CONTROL OF *BRACON BREVICORNIS* WASMEAL, A PARASITE OF *CORCYRA CEPHALONICA* ST., A HOST FOR MASS BREEDING OF *TRICHOGRAMMA MINUTUM* RILEY

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Bracon brevicornis Wasmeal has been recorded on Pink boll worm. It also attacks the caterpillars of *Corcyra cephalonica* St. which is employed for the mass production of *Trichogramma minutum* Riley. At times the attack of this *Bracon* is so serious that it destroys the entire culture of *Corcyra* and thus acts as a serious obstacle in the rapid multiplication of *Trichogramma* parasites. Although the *Bracon* is most active only during May, June and July, its slackened activity during the rest of the year, need not be neglected.

Behaviour and life-history

The adults are very active. After mating, the female rests on the body of the host larva and stings the host which dies subsequently. The parasite has a preference for the 3rd instar larvae. Larvae of 3·0 mm. or less are not attacked, whereas those which are more than 4·0 mm. long and well developed are readily parasitized. In cases of severe infestation, however, even the larvae in last instar or in the prepupal stage are usually not free from the attack. The parasite lays eggs anywhere on the body of the host or close to it. On an average, the duration of the life-cycle during May was eight days, (average maximum temperature 97·23°F.; minimum 73·22°F.; humidity at 8 o'clock 69·88 per cent).

Table I

Life-history of Bracon brevicornis

Eggs laid on	Eggs hatched on	Prepupal & pupal period	Date of emergence	Remarks
1-5-1943	2-5-1943	5th-8th	9-5-1943	Egg stage 1 day
3-5-1943	4-5-1943	7th-10th	11-5-1943	Grub stage 3 days
5-5-1943	6-5-1943	9th-12th	13-5-1943	Prepupal stage 1 day
6-5-1943	7-5-1943	10th-13th	14-5-1943	and Pupal stage 3 days
8-5-1943	9-5-1943	12th-15th	16-5-1943	
9-5-1943	10-5-1943	13th-16th	17-5-1943	
10-5-1943	11-5-1943	14th-17th	18-5-1943	
12-5-1943	13-5-1943	16th-19th	20-5-1943	
14-5-1943	15-5-1943	18th-21st	22-5-1943	

The number of parasites that develop from a single host depends on its size and may range from three to seven. The number of eggs laid by a single female ranged from 16 to 22 (Table II) and the oviposition period was two to three days, the maximum number of eggs being laid in the first 24 hours. The duration of the life of the adults was four to six days.

TABLE II

Egg laying and percentage of daily oviposition per female

Observation	Oviposition			Total	Percentage daily oviposition		
	1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.		1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.
1	8	6	2	16	50·0	37·5	12·5
2	7	4	5	16	43·7	25·5	31·3
3	10	6	3	19	52·6	31·5	16·0
4	9	5	3	17	53·0	29·4	17·6
5	10	4	4	18	55·5	22·2	22·2
6	11	5	4	20	55·0	25·0	20·0
7	9	6	4	19	47·4	31·6	21·0
8	12	7	3	22	55·0	32·0	13·0
9	11	6	4	21	52·4	28·6	19·0
10	10	6	5	21	47·6	28·6	23·8
Average	9·7	5·5	3·7	18·9	51·2	29·1	19·6

Description of stages. Adult : Active, male smaller than the female, average length male 3·55 mm., female 4·46 mm.; shows variation in the number of antennal segments which are 22 in male and 16 in female. The antennae are beaded except the last segment which is pear shaped, pedicel the smallest. Egg : Cigar shaped, grey, laid singly, average length 0·5 mm., hatches in about 24 hours in rare cases incubation period may extend to 30 hours. Grub : 0·5 mm. at emergence and on an average, becomes 2·07 mm. long when full grown, slightly curved, it feeds for two to three days, becomes stumpy, detaches itself from the host, and after the prepupal stage of one day, pupates in a silken cacoon. Pupa : slightly broader posteriorly ; average measurements, length 3·17 mm., breadth 1·14 mm.

Original description is given in *Nouv. Acad. Science Bruxelles*, 11 (1838) but the publication is not available anywhere in India.

MEASURES

Preventive

The food material should be spread in sun for a couple of days and well disturbed so that the parasitized larvae, if already present, may be killed. It is always safe to sun-dry even broken *Jowar* before it is used for this purpose.

The breeding cages should be well protected with wire gauze of 30 meshes to a liniar inch. and fumigated with tabacco before use. Soon after the inoculation of *Corcyra* eggs into the food material, breeding cages should be kept closed till the emergence of the moths. Just after collection of the moths, the cages should be carefully examined for any stray parasite which must immediately be destroyed. These precautionary measures must be adopted till practically all the moths have emerged.

Control

Light trap. Results of considerable significance have been achieved by light traps under laboratory conditions. A petromax light of 50 c.p. held in front of the breeding chamber at a distance of 2-5 ft. attracts innumerable parasites of which usually the greater percentage is of gravid females. The culture, however, should be disturbed to increase the efficacy of the trap. Almost 75 per cent control may be achieved by this method.

Ash method. As a rule, after emergence the parasites come to the surface for mating after which they again enter the culture through the interspaces and attack the host larvae. The larvae while feeding, often come near the surface of the food medium and are easily parasitized. Considerable control, however, has been achieved by spreading the ashes obtained by burning the molasses, which

is a byproduct in the manufacture of sugar, in thin and uniform layer of 1·0 cm. thickness over the culture. It provides an additional layer and, therefore, restricts the larval movement only within the food material. Moreover, the parasites after mating do not find easy access into the culture because the interspaces at the top are blocked up. Thus the larvae escape parasitization and breed within the culture quite undisturbed. The layer of ashes does not in any way hinder either the emergence of moths or the development of their larvae.

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STUDIES IN THE AGRONOMY OF GAORANI COTTONS

I. PREPARATORY TILLAGE AND INTERSEASONAL CULTIVATIONS

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IMPORTANCE of the preparatory tillage and interseasonal cultivation needs no special emphasis. Every farmer knows that if these basic operations of agriculture are not properly attended to, the yields of his crops are bound to suffer. Cotton yields in Marhatwada have been notoriously low and as such it was felt necessary to find out how far the same could be improved by bringing about suitable changes in the existing tillage operations. This work was started at the Cotton Research Station, Nanded, immediately after the evolution of a basic *bani* strain of cotton, viz. Gaorani 6.

Experiments

The local methods of preparatory tillage and interseasonal cultivations followed for cotton naturally depend upon the previous rotation crop grown in the field assigned for it. In Marhatwada cotton usually follows either *kharif* (monsoon) or *rabi* (cold weather) *jowar* (*Sorghum vulgare*). The cold season or *rabi jowar* is usually preceded by a short season leguminous crop of *mug* (*Phaseolus mungo*). In recent years, however, groundnut (*Archis hypogea*) is becoming widely popular as a rotation crop for cotton. Accordingly, the experiments regarding preparatory tillage and interseasonal cultivations for the same were carried out in relation to all these three crops that are rotated with it.

The local practices of preparatory tillage for cotton consist of :

(*a*) a ploughing (with a heavy wooden plough) once in four years, and

(*b*) annual *bakharings* with a blade harrow as per following details :

(1) After *kharif jowar :*

(i) Two *bakharings*, one immediately after *Ugadi*, i.e. middle of April and another after the break of south-west monsoon sometime in the first or second week of June ; or

(ii) Three *bakharings*, one immediately after *Ugadi*, i.e. middle of April ; another a month after the first *bakharing*, advantage being taken of any ante-monsoon showers that may be received and a third just after the break of south-west monsoon, sometime in the first or second week of June.

(2) After *rabi jowar :*

(i) One *bakharing* given just after the commencement of the south-west monsoon sometime in the first or second week of June; or

(ii) Two *bakharings*, one given immediately after the *Ugadi* and the other immediately after the commencement of the south-west monsoon ; or

(iii) Three *bakharings*, the first at *Ugadi*, second a month after *Ugadi* (advantage taken of any ante-monsoon showers) and third given just after the break of the south-west monsoon.

(3) After *groundnut :*

(i) Two *bakharings*, one immediately after the harvest of the groundnut crop (virtually a part of the harvesting operation itself) and another after commencement of the south-west monsoon.

The local methods of interseasonal cultivation consist of :

(*a*) two hoeings with *kolpa* (blade hoe); and

(*b*) one or two weedings carried out with the help of a *khurpi*, no difference being made due to previous rotations.

It will be noted from the above details of the preparatory tillage that these operations commence only after *Ugadi*, i.e. middle of April. This is probably due to the fact that the land leases in these parts are renewed on or about this day, which marks the beginning of the agricultural new year. The inevitable result of this practice is that the lands are totally neglected after the harvest of the

previous crop till the right for growing next year's crop is decided. It is usually believed that lack of preparatory tillage during this period may be responsible for lowering the yields of the following cotton crop. Accordingly in the experiment conducted after *kharif jowar*, where the land usually remains uncultivated for a long period till *Ugadi*, one *bakharing* immediately after its harvest was added to both the local practices cited above. Similarly, in case of groundnut rotation, an extra ploughing with an wooden plough in mid-January, or one bakharing at *Ugadi*, or both, were added to the existing local practice of preparatory tillage for cotton grown after this crop. In case of *rabi jowar*, however, the question of the land remaining uncultivated between harvest of *rabi jowar* and commencement of tillage operations for the following cotton, did not arise and as such the experiment was confined to the study of the effect of the increased frequency of *bakharing* operations after *Ugadi*.

Each of the preparatory tillage method in each experiment was studied in relation to the frequency of the weeding operations that formed a part of interseasonal cultivation for cotton.

Thus, each experiment consisted of eight treatments due to four levels of preparatory tillage (as detailed in Table I) and two levels of hand weedings, viz. once (on first workable day 35 days after sowing) or twice (on first workable days 30 and 65 days after sowing).

TABLE I

Details of prepartaory tillage treatments tested in the Cotton Cultivation Experiment A, Cotton Research Station, Nanded, 1942-45

After *kharif jowar*	After *rabi jowar*	After groundnut
(1)* Two *bakharings*—one after *Ugadi* and one after the break of south-west monsoon.	(1)* One *bakharing*—after the break of south-west monsoon.	(1)* Two *bakharings*—one at groundnut harvest, another after the commencement of south-west monsoon—ploughing once in four years.
(2) Three *bakharings*—one after harvest of *kharif jowar*, the other at *Ugadi* and the third after commencement of south-west monsoon.	(2)* Two *bakharings*—one after *Ugadi* and one after the break of south-west monsoon.	(2) Three *bakharings*—one at groundnut harvest, another at *Ugadi* and third after commencement of the south-west monsoon—ploughing once in four years.
(3)* Three *bakharings*—one after *Ugadi*, one after a month and the third after the break of south-west monsoon.	(3)* Three *bakharings*—one after *Ugadi*, one a month later and one after break of south-west monsoon.	(3) Two *bakharings*—one at groundnut harvest, another after the commencement of south-west monsoon—ploughing once in two years.
(4) Four *bakharings*—one after harvest of *kharif jowar*, one at *Ugadi*, one a month later and one after the break of south-west monsoon.	(4) Four *bakharings*—one after *Ugadi*, one each in April and May at successive intervals of three weeks after *Ugadi bakharing* and one after the break of south-west monsoon.	(4) Three *bakharings*—one at groundnut harvest, another at *Ugadi*, and third after commencement of the south-west monsoon—ploughing once in two years.

* Local practices

In addition to the above treatment operations all the plots of cotton whether grown after *kharif jowar*, *rabi jowar* or groundnut were subject to usual hoeing operations.

Each experiment consisted of five randomized blocks, each block having eight plots—one corresponding to a treatment. Each plot was $60\frac{1}{2}$ ft. $\times 19\frac{1}{2}$ ft. and had 12 rows, each row being $60\frac{1}{2}$ ft. long, distance between rows being 18 in. Two rows on either flank of the plot and 2 ft. 9 in. length of each row on either extremity were treated as non-experimental. The net plot size was, therefore, 1/66 acre—55 ft. $\times$ 12 ft.

The experiments were conducted during the seasons 1942-43, 1943-44 and 1944-45 at the Cotton Research Station, Nanded, where the soil is a typical black cotton one. The seed of Gaorani 6 was

sown each year at the usual time, exactly as per the local practice of dropping the same through a *mogha* (tube) running behind a *bakhar*.

All the fields had received a tractor ploughing in May 1940 and four years later ploughing with a country plough was given at *Ugadi*, so that differences due to this routine tillage operation were not possible.

In addition to the above experiments regarding preparatory tillage for cotton grown after three rotation crops, another test was conducted during the period 1941 to 1944 to study exclusively the effect of the different methods of interseasonal operations with varying frequencies on the yield of Gaoranib. This experiment was carried out after *kharif jowar* under normal conditions and consisted of the 18 treatment combinations due to three levels of weeding, three levels of hoeing with a bullock hoe and two levels of ridging with Indore ridger. Details of these treatments were as follows :

(*a*) *Weedings* (with a *khurpi*)

(1) No weeding.

(2) Weeding once, on the first workable day following 35 days after sowing.

(3) Weeding twice—first weeding on first workable day following 30 days after sowing, second weeding on first workable day following 65 days after sowing.

(*b*) *Hoeing* : with a *kolpa* (blade hoe) worked by bullocks.

(1) No hoeing.

(2) Hoeing once—on the first workable day following 40 days after sowing.

(3) Hoeing twice—first hoeing on the first workable day following 35 days after sowing and second hoeing on the first workable day following 70 days after sowing.

(*c*) *Ridging* : with Indore ridger worked by bullocks

(1) No ridging.

(2) Ridging once—about 80 days after sowing.

The layout of this experiment consisted of three randomized blocks, each block having 18 plots arranged at random. Each plot had 11 rows, 18 in. apart, two rows on either side and 2 ft. 9 in. length on either extremity of all rows being treated as non-experimental so that the net plot size was 1/75·4 acres.

Results

The results of the analyses of variance obtained for yield of seed cotton recorded for three seasons in the experiments mentioned above are given in Tables II, III and IV.

Table II

Analyses of variance for the yields of cotton obtained for three seasons in the cotton cultivation tests conducted at the Cotton Research Station, Nanded, during 1942-45

Due to	Degree of freedom	Mean square of variance	
		After *kharif jowar*	After *rabi jowar*
Seasons	2	11121·5**	16308·7**
Blocks within seasons	12	405·6	206·5**
Bakharings	3	613·4	8·7
Weedings	1	80·4	849·1**
Bakharings × weedings	3	78·8	40·1
Seasons × weedings	2	250·2	240·3
Seasons × *bakharings*	6	81·0	61·9
Seasons × *bakharings* × weedings	6	39·7	57·3
Error	84†	256·6	57·7

† 83 degrees of freedom for *kharif jowar* since one plot in 1943-44 was missing. Similarly 82 degrees of freedom for *rabi jowar* as yield of two plots in 1943-44 were lost and as such calculated as missing.

** Significant at 1 per cent level.

TABLE III

Analysis of variance for yields of seed cotton for the three seasons, 1942-45, in the cultivation test after groundnut

Due to	Degrees of freedom	Mean square	Remarks
Blocks	12	1572·3	
Seasons	2	2578·1	
Weedings	1	262·8	
Bakharings	1	563·3	
Ploughings	1	276·6	
Seasons × weedings	2	421·9	
Seasons × *bakharings*	2	85·9	
Seasons × ploughings	2	10·2	
Bakharings × weeding	1	6·3	
Ploughing × weeding	1	14·4	
Ploughing × *bakharing*	1	105·3	
Seasons × *bakharings* × weeding	2	195·2	
Seasons × *bakharings* × ploughing	2	1206·4	
Seasons × ploughing × weeding	2	192·8	
Ploughing × weeding × *bakharing*	1	626·5	
Season × ploughing × weeding × *bakharing*	2	230·6	
Error	83*	257·8	* Yield of one plot in 1944-45 lost—treated as missing

It will be seen from the above analyses of variance that none of the preparatory tillage treatments incorporated in any of the above experiments brought about any 'Significant' differences in the yield of *kapas* of Gaorani 6.

The mean yields of *kapas* (lb. per acre) obtained in the trial for different preparatory tillage treatments for three seasons were as follows :

(1) *After* kharif jowar :

	Bakharings				Mean	S. E.
	Twice—(1) at *Ugadi* and (2) after break of South-West monsoon	Thrice—(1) after *kharif jowar* harvest (2) at *Ugadi* and (3) after break of South-West monsoon	Thrice—(1) at *Ugadi* (2) a month after (3) after break of South-West monsoon	Four times—(1) after *kharif jowar* harvest (2) at *Ugadi* (3) a month after (4) after break of South-West monsoon		
1942-43	194	182	226	203	201	17·5
1943-44	348	317	343	323	333	24·6
1944-45	320	264	324	299	302	18·1
Average for three seasons	287	254	298	275	278	12·1

(2) *After* rabi jowar :

	Bakharings				Mean	S. E.
	Once—after break of South West monsoon	Twice—(1) at *Ugadi* (2) after break of South-West monsoon	Thrice—(1) at *Ugadi* (2) a month after (3) after break of South-West monsoon	Four times—(1) at *Ugadi* (2) and (3) three weeks interval (4) after break of South-West monsoon		
1942-43 . . .	191	183	194	195	191	6·6
1943-44 . . .	108	118	122	129	119	13·1
1944-45 . . .	300	284	283	274	285	8·9
Average for three seasons	200	195	200	200	199	5·7

(3) *After groundnut :*

	Ploughing once in four years		Ploughing once in two years		Mean	S. E.
	Two *bakharings* (1) after groundnut harvest (2) after break of South-West monsoon	Three *bakharings* (1) after groundnut harvest (2) after *Ugadi* (3) after break of South-West monsoon	Two *bakharings* (1) after groundnut harvest (2) after break of South-West monsoon	Three *bakharings* (1) after groundnut harvest (2) after *Ugadi* (3) after break of South-West monsoon		
1942-43 . . .	264	267	288	276	274	17·3
1943-44 . . .	343	253	298	328	306	26·3
1944-45 . . .	333	341	366	318	339	18·3
Average for three seasons	312	287	317	307	306	20·9

Thus it will be seen that increase in the frequency of preparatory tillage operations for cotton to be grown after any of the crops mentioned above does not contribute towards any increase in its *kapas* yield.

Similarly the effect of an extra weeding (in addition to one that must be given) did not show any significant increase in the yield of seed cotton except in case of its being grown after *rabi jowar*. The mean yields of *kapas* (lb. per acre) for three seasons, 1942 to 1945, of Gaorani 6 due to different weeding treatments in the three trials were as follows :

	Weedings with *khurpi*		S. E.	C. D. at 5 per cent
	One only	Two weedings		
After *kharif jowar*	275	282	8·5	—
After *rabi jowar*	188	210	4·0	11·2
After groundnut	300	312	8·6	—

It has been already mentioned that in addition to above experiments, still another cultivation test was conducted to study the effect of different interseasonal cultivation practices on the yield of seed cotton when grown after *kharif jowar*. Table IV gives the analyses of variance for the yield of *kapas* recorded in this experiment for three seasons. A combined analysis for three years' data was not possible due to existence of large differences in the error variances of the three seasons' trials.

TABLE IV

Analyses of variance for yield of seed cotton in the cultivation test 'B' (for post-cultivation operations) conducted at the Cotton Research Station, Nanded, 1941-1944

Due to	Degrees of freedom	Mean square		
		1941-42	1942-43	1943-44
Blocks	2	818·1	492·4	1953
Weedings	2	81538·1**	14450·2**	26046**
Hoeings	2	2230·1	1533·4**	268
Ridgings	1	3639·2	121·0	2334
Weeding × hoeings	4	1865·9	56·4	461
Hoeing × ridging	2	631·7	42·1	589
Weeding × ridging	2	3121·5	91·1	831
Weeding × hoeing × ridging	4	2470·8	84·5	930
Error	34	2861·7	111·4	849·4

**In 1943-44 there ware only 33 degrees of freedom due to yield of one plot being lost (missing plot)

It will be seen from the above analyses that the differences due to 'ridging' were not significant in any of the seasons. This means that Indore ridger does not offer any advantage to the Marhatwada cultivator.

The differences in *kapas* yield due to weedings were significant for all the three seasons and mean yields (lb.) per acre due to these treatments were as follows :

	Pounds per acre			S. E.	Critical difference at 5 per cent level
	No weeding	One weeding	Two weedings		
1941-42	561	*1083*	*1134*	59	171
1942-43	96	*311*	*341*	12	34
1943-44	94	297	452	32	93

It will be seen that the weeded crop gave a significantly higher yield than the unweeded one. This is least surprizing since the weed competition is sure to lower the yields of any crop. It was further noted that, whereas in the first two seasons only one weeding was sufficient, in 1943-44 a second weeding gave a genuine advantage to the crop. This was probably due to the fact that in this particular season abnormally continuous rains after first weeding were recorded so that an additional weeding after it was beneficial.

Hoeing once or twice with a *kolpa* did not offer any benefit during the seasons 1941-42 and 1943-44. However, in 1942-43, the plots that received hoeing gave a significantly higher yield over the ones that were not 'hoed'. There was, however, no difference in yield of *kapas* due to the number of hoeings. The mean *kapas* yields for these treatments for the three seasons were as follows :

	Pounds per acre			S. E.	Critical difference at 5 per cent
	No hoeing	One hoeing	Two hoeings		
1941-42	*987*	*903*	*889*	59	—
1942-43	200	*273*	*276*	12	34
1943-44	*269*	*266*	*299*	32	—

The above results show that hand weeding with a *khurpi* alone is an absolutely essential post-sowing operation of the cotton crop.

Discussion

The experiments described above clearly show that, so far as preparatory tillage with the *desi* implements is concerned, the present methods followed by the Marhatwada cultivator need no improvement. This should not be surprizing in view of the fact that the local practices of to-day are an outcome of the trial and error methods extending over centuries. The neglect of the land between the previous harvest and *Ugadi* (the Agricultural New Year) as brought about by the present system of land tenure, so far as the preparatory tillage is concerned, does not seem to have any untoward effect on the following cotton crop.

Weeding forms a very important interseasonal operation of cotton cultivator without which the yields suffer very considerably. The frequency of useful weedings, however, would naturally depend upon the distribution of the rainfall, which in its turn controls the density and growth of the weeds. It is the competition effect of the weeds that has to be guarded against. This weeding operation is usually done by cultivator by such implements as serve a dual purpose, viz. that of weed removal and soil mulch. The above experiment has shown that in such matters, the common *khurpi* is more efficient than either the blade hoe (*kolpa*) or the 'Indore ridger'. This is probably due to the fact that the effect of 'blade hoe' is usually limited to the mulching and weeding of a 6—8 in. soil strip only, that lies between the crop rows 18 in. apart. Further, its deeper penetration in the soil has probably a disturbing effect on the root system. In case of ridging, the same effects are present in a greater degree. *Khurpi*, on the other hand, leaves no patch of the soil unmulched or unweeded and also gives the least disturbance to the roots. Further the blade hoe (*kolpa*) and ridger worked with bullocks offer possibilities of injury to the crop by the treading of the animals.

Previous work regarding preparatory tillage conducted by the different Provincial Departments of Agriculture is mostly confined to the efficiency of 'inversion' ploughs. An exhaustive review of this by Allan [1935] shows that in the black cotton soil tracts use of inversion plough has no particular advantage in improving the yields of crops over a country plough and that their utility was not marked anywhere except at places where weed control was a problem. Ramanatha Iyer *et al.* [1940] found that, in Madras, the differences in yield due to preparatory tillage treatments of ploughing and *bakharing* (*Guntaka*) were of insignificant order. The results of the present tillage experiments, although not strictly comparable with the ones where other types of implements are used, show that the conclusions of Russel and Keen [1938] that "Cultivations in excess of those needed to produce a seed bed and to keep down the worst of weeds did not confer any further benefit.........." are upheld. These conclusions apply more particularly to soils that are virtually exhausted through continuous cultivation without adequate manuring.

Summary

Cultivation experiments with Gaorani 6 cotton conducted at the Cotton Research Station, Nanded, during the period 1941-45 showed that:

1. Variations in frequencies and timings of *bakharings* and ploughings in preparatory tillage for cotton grown after *kharif* or *rabi jowar* or after groundnut did not improve yield of Gaorani 6.

2. A weeded crop gave a significantly higher yield than the unweeded one. One weeding should be normally enough since additional weeding did not offer any extra benefit except in years of abnormally late rains.
3. *Khurpi* is the most suitable implement for intercultivation operations in Marhatwada.

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UTILIZATION OF TOMATOES FOR JUICE AND SEED EXTRACTION

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Tomato seed, a waste product in juice manufacturing factories, is utilized for extraction of seed oil in Italy [Sanborn, 1945] which is chiefly used in soap making. Waste material from manufactured tomato products is also used as cattle feed in America and Italy [Wiegand, 1944 ; Sanborn, 1945], owing to its high nutritive value particularly protein content. No mention appears to have been made in the literature particularly in India about the utilization of tomatoes both for purposes of juice and seed extraction.

Baluchistan is eminently suited for growing tomatoes of excellent quality. The yield per acre is also very high and ranges from 20 to 25 tons. In the uplands, tomatoes are available from June to October and are especially prolific during July to September. In the lower lands of the Province, they are available during winter months. There are, at present, seven registered seed growers who produced about 47,710 lb. of vegetable seeds including 400 lb. of tomato seed in 1944. In 1945, about 2,000 lb. tomato seed was produced. A few small concerns are also engaged in the manufacture of various tomato products in Quetta and Gulistan.

The attention of the authors was drawn to the enormous wastage of juice occurring during seed extraction process and of the seed when juice making is the primary object. This wastage is bound to be further increased as the production of seed or juice increases. An effort was, therefore, made to utilize whole tomatoes for extraction of juice as well as seed so as to avoid wastage of the either product. In the following pages, treatment of tomatoes prior to juice extraction, extraction of juice and seed, preservation of juice, cost of production of juice and seed, etc., are discussed. A method of extraction of juice and seed is also described.

A problem of great economic importance both from the view point of vegetable seed growers and tomato juice manufacturers has been solved. It is to the mutual advantage of the seed growers and juice manufacturers to cooperate among themselves to avoid wastage of juice or seed. On the basis of tomato seed produced in 1945 by the registered seed growers of Quetta, not less than 133,400 lb. juice (about 1627 maunds) sufficient to produce about 74,000 cans of A2½ size was allowed to go to waste. Similarly, a huge amount of tomato seed is wasted by juice manufacturing concerns situated in seed raising parts of India, e.g. Baluchistan, Kashmir, etc. The wastage of either product can be avoided if the recommendations made in this article are followed. Their production costs would also considerably decrease and thus the producers as well as the consumers will be immensely benefited.

Methods

The method of juice manufacture as described by Lal Singh and Girdharilal [1944], was found to be best suited for the simple type of equipment available in these laboratories and was adopted with slight modifications. The usual fermentation method of tomato seed extraction was employed.

Raw material

Tomatoes of a variety locally known as Large Red, grown at the Fruit Experiment Station, were used. The fruit was medium large to large in size (weighing about six fruits to a lb.) and having a smooth surface and roundish shape. The fruit was allowed to remain on the bushes till it was fully mature and had developed a deep red colour. Individual fruits were then picked in to slat bottom wooden trays and brought to the laboratory.

Experimental

Experiments on extraction of juice and seed from whole tomatoes were conducted for two seasons, viz. 1943 and 1944. In 1943, fully ripe tomatoes were sorted, washed, trimmed and were mashed

into pulp by hand. A certain amount of juice expressed during the mashing process contained a fairly large percentage of the seed. This juice was separated by decantation and passed through monel metal sieve of 1 mm. mesh. The seed collected on top of the sieve was allowed to remain with a little quantity of juice in three different types of containers, viz. aluminium, earthenware and wooden for about two days during which period the mass fermented and seed settled down. The supernatant liquid was then poured off, seed washed with water and dried in shade. The remaining juice along with pulp was heated. for about five minutes, in a steam jacketed pan and juice extracted by working the pulp over monel metal seive of 1 mm. mesh. The juice was then immediately brought to a boil, sodium chloride added at the rate of 1 per cent. filled and processed [Lal Singh and Girdharilal, 1944]. The time of processing was increased to suit local conditions [Siddappa, 1942]. The experimental data collected, are given in Tables I and II.

TABLE I

Tomato seed extraction (1943)

Expt. No.	Date	Variety	Weight of tomatoes taken in lb.	Weight of rejected tomatoes (being over-ripe) in lb.	Container used for seed extraction	Weight of seed obtained	Colour of the seeds	Yeild per maund of tomatoes	Remarks
1	2	3	4	5	6	7	8	9	10
1	2-9-43	Local	200	10	Earthenware	(473 gm.) 16·70 oz.	Medium dull straw	6·85 oz.	The pulp left after seed extraction along with the juice extracted during the process was used for making tomato juice.
2	4-9-43	,,	165	10	Wooden	(388 gm.) 13·69 oz.	Light dull straw	6·80 ,,	Do.
3	7-9-43	,,	197	6	Aluminium	(470 gm.) 16·61 oz.	Deep dull straw	6·90 ,,	Do.

TABLE II

Tomato juice from whole tomatoes and from pulp after seed extraction (1943)

Expt. No.	Date	Variety	Weight taken in lb.	Weight rejected (over-ripe) in lb.	Process	Juice extracted during seed extraction in lb.	Juice from pulp left after seed extraction in lb.	Total Juice extracted in lb.	No. of 24 oz. bottles prepared	No. of bottles broken during processing	Remarks
1	2	3	4	5	6	7	8	9	10	11	12
1	31-8-43	Local	200	8	Used whole tomatoes	..	..	119	75	3	....
2	2-9-43	,,	200	10	Used pulp left after seed extraction	24	90	114	69	4	About 5 lb. of juice was allowed to remain with the seeds to facilitate fermentation and settling process.
3	4-9-43	,,	165	10	Do.	19	78	97	57	3	Do.
4	7-9-43	,,	197	6	Do.	28	87	115	68	3	Do.

The above method was considered to be rather uneconomical as a fairly large percentage of seed remained in the pulp and could not be separated by the decantation of the juice. In 1944, on the basis of small scale experiments, the following procedure was adopted for extraction of juice and seed rom whole tomatoes.

After preliminary treatments of sorting, washing and trimming, the tomatoes were cut into halves, the locules containing seed were separated and the skin halves kept aside. The pulp from locules was worked over monel metal sieve of 1 mm. mesh and the seed remaining on top with coarse pulp was allowed to ferment for 24-48 hours in wooden containers. This material was then gently rubbed with hands and seed separated by immersion in cold water. The skin halves were mashed, heated in a steam pan for about five minutes and juice extracted in the same manner as from locules. This was mixed with the juice obtained from locules, the entire lot quickly brought to a boil and finally packed as mentioned above. For comparing the quality and production costs of juice as well as of seed, whole tomatoes were utilized for preparation of juice and seed separately. The juice was packed precisely in the same manner as described by Lal Singh and Girdharilal [1944], while for extraction of seed the whole tomatoes were mashed with hands after crushing [Lal Singh and Girdharilal, 1940], left for 24-48 hours and then rubbed with hands and the seed separated by immersion in cold water. Germination percentage of seed samples was determined by putting 100 seeds of each lot in folds of muslin cloth (kept constantly wet by immersion of its ends in water) placed in a constant temperature incubator (temperature 28-30°C.) for about 10 days and counting the number of seeds which had germinated during this period. The germination tests were conducted by about the end of November, 1944. The entire experimental data are given in Tables III to V.

Discussion of results

A perusal of the experimental data presented in Tables I and II would reveal that:

1. Out of three containers used for tomato seed extraction wooden containers gave seed of a light dull straw colour which was better in general outward appearance than that obtained either from earthen ware or aluminium vessels.

2. When tomatoes were used for juice extraction alone, 59·5 lb. of juice was obtained from 100 lb. of fruit; and when both juice and seed were extracted, the yields of juice and seed per 100 lb. of fruit were 57 lb. and 8·4 oz. respectively. The decrease in the yield of juice was more than offset by the income realized from the sale of seed. Cost of production of juice worked out on the basis of a typical experiment in 1943 was as follows:

(a) *Juice from whole tomatoes (experiment 1 of Table II)*

1. Cost of 200 lb. tomatoes at Rs. 8 per md. of 82 lb.	Rs. 19-8-2
2. Coal 4 md. at Re. 1 per maund	4-0-0
3. Salt 1·2 lb.	0-1-4
4. Labour 3 men at Re. 1 per man per day	3-0-0
5. Miscellaneous charges, e.g. cloth, preservative, etc.	0-9-0
6. Cost of 75 bottles of 24 oz. capacity at Rs. 4-14 per dozen	30-7-6
7. Cost of 75 crown corks at 3 pies each	1-2-9
TOTAL	58-12-9

Net number of bottles prepared (after deducting breakage) 72

Cost per bottle of 24 oz. capacity (exclusive of depreciation and supervision charges and cost of labelling which will amount to at one anna per bottle approximately) 0-13-1

(b) *Juice from pulp left after seed extraction (experiment 2 of Table II)*

1. Cost of 200 lb. of tomatoes at Rs. 8 per maund of 82 lb.	Rs. 19-8-2
2. Coal 4 md. at Re. 1 per md.	4-0-0
3. Salt 1·1 lb.	0-1-3
4. Labour five men at Re. 1 per day	5-0-0
5. Miscellaneous charges, e.g. cloth, preservative, etc.	0-9-0
6. Cost of 69 bottles at Rs. 4-15 per dozen	28-0-6
7. Cost of 69 crown corks at pies 3 each	1-1-3
TOTAL	58-4-2
Income from the sale of 16·7 oz. tomato seed at Rs. 20 per lb. (the actual retail price fixed by the Government ranged from Rs. 12-8 to 30 per lb.)	20-14-0
Net cost on juice	37-6-2

Net number of bottles prepared 65

Net cost per bottle of 24 oz. capacity (exclusive of depreciation, supervision and labelling charges) 0-9-2

It is evident from the above that the cost of fruit is out-balanced by the income from sale of seed and in consequence of this the cost of production of juice is reduced by about 30 per cent.

Data of detailed experiments conducted during the 1944 season on the utilization of whole tomatoes for juice, seed and juice plus seed extraction given in Tables III to V, indicate the following :

(A) *tomato juice from whole tomatoes (Table III)*

TABLE III

Results of tomato juice extraction from whole tomatoes (1944)

Expt. No.	Date	Net weight of tomatoes taken in lb.	Weight of trimmings, skins, etc. in lb.	Percentage of loss due to trimming	Weight of juice in lb.	Percentage recovery of juice	Weight of water added in lb.	Percentage of waater added in the juice in lb.	No. of cans prepared (A 2½)	Remarks
1	2	3	4	5	6	7	8	9	10	11
1	18th July	90·5	27·5	30·39	63	69·61	10·	15·87	41·	Rather abnormal rejecton
2	21st ,,	332	74	22·29	258	77·71	61	21·81	179	Good quality tomatoes—good yield of juice
3	24th ,,	162·5	42·5	26·15	120	73·85	30	25·0	81	Good quality tomatoes—good yield of juice
4	25th ,,	141·5	41·5	29·33	100	70·67	25	25·0	71	Rather abnormal rejection and low yield of juice
5	4th Sept.	92	36	39·13	56	60·87	19	33·93	43	Abnormal rejection—yield of juice rather low
6	11th ,,	396	101	25·50	295	74·5	30	10·17	173	Good quality raw material—good yield of juice
7	25th ,,	276	64	23·20	212	76·8	*Nil*	×	111	Good quality raw material—good yield of juice but of rather thin consistency
8	27th ,,	230	52	22·61	178	77·39	*Nil*	×	96	Good quality raw material—good yield of juice but of rather thin consistency
9	29th ,,	256	58	22·66	198	77·34	*Nil*	×	110	Good quality raw material—good yield of juice but of rather thin consistency
10	30th ,,	335	73	21·79	262	78·21	*Nil*	×	141	Good quality raw material—good yield of juice but of rather thin consistency
11	4th October	437	120	27·46	317	72·54	*Nil*	×	174	Good quality raw material—good yield of juice but of rather thin consistency
From 100 lb. tomatoes		2748·5	689·5 25·09	..	2059 74·91	..	..	..	1220 44	

1. One thousand two hundred and twenty cans (A 2½ plain) of juice were obtained from 2748·5 lb. tomatoes or 44 cans from 100 lb. fruit.

2. Juice of thicker consistency was obtained in the early and mid season than that from the late season's crop.

3. The wastage percentage varied from 21·79 to 39·13 and the yield of juice from 60·87 to 78·21 : the average figures being 25·09 and 74·91, respectively. This is a better yield than that reported by Lal Singh and Girdharilal [1944] and is mainly due to the high quality of raw material.

4. The juice was of a rich red colour and had a nice flavour and taste and kept very well during about 1½ year's storage.

5 Approximate cost of production of an A $2\frac{1}{2}$ can of juice was as follows :

(1) Cost of 2748·5 lb. tomatoes at As. 2 per lb.	Rs. 343-9-0
(2) Salt 20·6 lb. at Rs. 6 per maund	1-8-0
(3) Coal 1 md. for 50 cans at Re. 1 per md.	24-8-0
(4) Labour 1 man for 30 cans at Re. 1 per day	40-10-0
(5) Cost of 1220 cans at 36·98 pies per can inclusive of reforming charges . . .	235-0-0
(6) Miscellaneous charges, e.g., electricity, labels, supervision, depreciation, allowance for spoilage, etc. at anna 1 pies 6 per can	114-6-0
Total cost on 1220 cans .	759-9-0
Cost per can (A$2\frac{1}{2}$ plain) . . .	0-10-0

(B) Tomato seed from whole tomatoes (Table IV)

TABLE IV

Results of tomato seed extraction from whole tomatoes (1944)

Expt. No.	Lot no. of seed	Date	Weight of tomatoes taken in lb.	Weight of seed obtained in gm.	Percentage recovery of seed	Germination percentage of seed	Remarks.
1	2	3	4	5	6	7	8
12	3	21st July	150	692	1·02	93	Light dull straw, good appearance, good recovery
13	6	26th ,,	145	610	0·93	95	Light dull straw, attractive appearance, good recovery
14	7	29th ,,	134	542	0·89	93	Light dull straw, attractive colour, good outturn
15	8	31st ,,	210	744	0·78	80	Light dull straw, attractive colour, good yield
16	9	12th September	58	140	0·53	96	Medium dull straw, good appearance, fairly good recovery
17	$\frac{10}{11}$	18th ,,	152	456	0·66	84·75	Medium dull straw, good colour, fairly good recovery
18	12	25th ,,	30	57	0·42	94	Medium dull straw, good colour, fairly good recovery
19	$\frac{14}{15}$	10th October	120	79	0·15	60	Dull straw colour, low recovery, low germination percentage. Poor sample
			999	3320 or 7·3 lb.			
		From	100 lb.	332·3 or 0·73 lb.			

1. Nine hundred and ninety-nine lb. tomatoes were required for 7·3 lb. of seed, i.e. 100 lb. for 0·73 lb.
2. Percentage of seed recovery on fresh tomatoes varied from 0·15 to 1·02, the average figure being 0·67.
3. A higher yield of seed was obtained in the early season which gradually decreased as the season advanced. There was a marked decrease in the yield of seed obtained on the 10th October which considerably lowered the average figure. A detailed investigation in this connection is in hand.
4. The seed was of a high quality both in regard to its general appearance and germination power which varied from 60 to 96, the average being 85·6.
5. A seed of rather poor quality was obtained in the late season and its germination power also seemed to be impaired as the season advanced.
6. Approximate cost of production per lb. of seed was as follows :

(1). Cost of 999 lb. tomatoes at As 2 per lb.	Rs. 124-14-0
(2) Labour charges—two men for 100 lb. fruit at Re. 1 per head per day . .	20-0-0
Total cost of 7·3 lb. seed . .	144-14-0
Cost per lb.	19-13-6

(C) *Tomato juice and seed (Table V)*

TABLE V

Results of tomato juice and seed extraction from whole tomatoes (1944 season)

Expt. No.	Lot No. of seed	Date	Net weight of tomatoes taken in lb.	Weight of trimmings and skins etc. in lb.	Percentage of loss due to trimming	Weight of juice in lb.	Percentage recovery of juice	No. of cans prepared (A 2½)	Quantity of seed in gm.	Percentage of fresh tomatoes	Germination percentage of seed	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
20	1	18th July	143	49	34·27	94	65·73	53	617	0·95	91	Good yield of juice and seed. High germination percentage.
21	2	21st ,,	126	38	30·16	88	69·84	47	630	1·10	96	Good yield of juice and seed. High germination percentage.
22	4	24th ,,	78·5	30·5	38·85	48	61·15	27	300	0·84	94	Good yield of juice and seed. High germination percentage.
23	5	25th ,,	106·5	33·5	31·46	73	68·54	39	497	1·03	100	Good yield of juice and seed. High germination percentage.
			454	151·0		303		166	2044	or 4·5 lb.		
From 100 lb.					33·26		66·74	37	450·2	or 0·99 lb.		

1. One hundred and sixty-six cans (A $2\frac{1}{2}$ plain) of juice and 4·5 lb. seed were obtained from 454 lb. fruit, i.e. 37 cans of juice and about 1 lb. seed from 100 lb. fruit respectively.

2. The wastage percentage varied from 30·16 to 38·85 and recovery of juice from 61·15 to 69·84; the average figure being 33·26 and 66·74, respectively. The yield of juice is thus slightly decreased when seed extraction is resorted to.

3. The recovery of seed was 0·84 to 1·10 per cent of fresh fruit, the average being 0·99. This is a very high figure when compared to the results of 1943 season where, approximately, 0·52 lb. seed was obtained from 100 lb. tomatoes. This may be attributed to several causes, e.g. the quality of raw material, seasonal variations, etc., but the improved method adopted for seed extraction in 1944 season seems to be chiefly responsible for increased recovery of seed.

4. The seeds had an attractive outward appearance; their germination power ranged from 91 to 100 per cent, the average being 95·25.

5. The juice had a rich red colour, nice taste and kept very well in about $1\frac{1}{2}$ year's storage. It had a marked tendency to separate into liquid and pulpy portions. This defect is however not very serious when the juice is packed in cans.

6. Approximate cost of production of an A $2\frac{1}{2}$ can of juice was as under:

(1) Cost of 454 lb. tomatoes at As. 2 per lb.	Rs. 56-12-0
(2) Salt 3 lb. at Rs. 6 per md.	0-3-0
(3) Coal 1 md. for 50 cans at Re. 1 per md.	3-5-0
(4) Labour 1 man for 20 cans at Re. 1 per day	8-5-0
(5) Cost of 166 cans at 36·98 pies per can inclusive of reforming charges	32-0-0
(6) Miscellaneous charges, e.g. electricity, labels, depreciation, supervision, and allowance for spoilage, etc. at anna 1 pies 6 per tin	15-9-0
Total cost on 166 cans	116-2-0
Cost per tin	11-2-0
Deduct from this the cost of 4·5 lb. seed at Rs. 14 per lb. (Rs. 15 per lb. being the approved wholesale price for first class quality seed—the retail price being Rs. 30 per lb. minus Re. 1 per lb. on account of proportionate labour charges on seed extraction), i.e.	63-0-0
Net cost on 166 cans	53-2-0
Cost per can	0-5-0

The production cost is thus reduced by 50 per cent, when only juice is manufactured the cost being 10 annas per can.

General recommendations

During all stages of handling tomatoes for juice and seed extraction, contact with metals like iron, copper, zinc, lead, etc. should be avoided. For juice extraction, stainless steel, aluminium, nickle, glass lined equipment, nickle-copper alloys like monel metal can be safely used. For seed extraction, wooden containers or earthen ware can be employed with advantage. As a result of the investigation reported above, the following method for extraction of tomato juice and seed from whole tomatoes on a semi-commercial scale is recommended.

Step I. Select fully ripe red coloured tomatoes reasonably free from cracks. Wash thoroughly by soaking them in water in cemented tanks and then by holding under strong sprays of water. Remove carefully green and blemished portions, if any.

Step II. Cut the fruit into halves, remove the locules containing seeds and keep aside the skin halves. Work the pulp (from locules) over 1 mm. mesh monel metal or stainless steel sieve and collect the juice and seed (along with the coarse pulp) thus separated and proceed as follows :

Seed. Keep the seed in wooden containers or earthenware for 24-48 hours for fermentation, then rub it gently with hands and separate the seed by immersion in cold water in suitable containers. The coarse material will float on top leaving the clean seed at the bottom of the container. Dry the seed in shade and when perfectly dry, pack in suitable cardboard or other containers.

Juice. Heat the skin halves for three to five minutes in an open aluminium vessel on direct fire or in a steam jacketed kettle. Strain through a sieve of 1 mm. mesh made of monel metal or stainless steel [Lal Singh and Girdharilal, 1940] or pass the mass through a pulping or straining machine [Lal Singh, Giridhari Lal and Mohd Ishaq, 1943]. Mix the juice thus obtained with that extracted from the locules. Bring the entire lot quickly to a boil, regulate total solids content [Cruess, 1938] and proceed as described by Lal Singh and Girdhari Lal [1944, (Step III)], taking care that processing time is regulated according to the height of the place where work is conducted.

For work on commercial scale, use of a crusher consisting of two revolving adjustable grooved wooden rollers placed horizontally for crushing tomatoes and of a pulping or straining machine for removing seed and skin are believed to be highly beneficial. It is, however, to be seen whether the germination power of seed is affected by thorough scrubbing of the material with the revolving brushes of the pulping machine. Due to the non-availability of these machines, this aspect of the problem could not be studied.

Summary

A critical study has been made on the following aspects of utilization of tomatoes for juice, seed and juice plus seed extraction, viz. (a) preliminary treatments of sorting, washing and trimming, (b) extraction of juice, (c) extraction of seed, (d) suitability of various containers for seed extraction, (e) cost of production of juice and seed, and (f) germination power of seed. A problem of great economic importance both from the view point of vegetable seed growers and tomato juice manufacturers has been solved. Results are briefly indicated below :

Out of the three types of containers used, viz. aluminium, wooden and earthenware for seed extraction, wooden containers yielded the best product.

When tomatoes were used for juice extraction alone, 44 cans (A2½ plain) were obtained from 100 lb. fruit and the cost of production per can was annas 10.

0·73 lb. of seed was obtained from 100 lb. tomatoes when exclusively utilized for seed extraction and the cost of production of seed was Rs. 19-13-6 per lb.

When tomatoes were utilized for juice as well as for seed extraction, 37 cans (A2½ plain) of juice and about 1 lb. of seed were obtained from 100 lb. fruit. The additional cost on seed extraction was Re. 1 per lb. and the cost of production of an A2½ size can of juice (after making an allowance for the value of the seed extracted) came to annas 5 only.

The quality of juice and seed obtained under various treatments was very good and the juice kept very well in about $1\frac{1}{2}$ years' storage.

Juice and seed of rather inferior quality were obtained from the late season's crop than from the tomatoes collected in the early or mid season. The percentage recovery of the seed seemed to decrease as the season advanced and its quality and germination power also seemed to be impaired.

A method for extraction of juice and seed from whole tomatoes has been described.

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SOME FUNGI FROM ASSAM, II

By S. Chowdhury, Plant Pathological Laboratory, Sylhet, Assam

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(With two text-figures)

THIS is the author's second contribution to the study of Assam fungi. The collections were made during 1943 and 1944. In the identification of a few fungi help was received from Dr B. B. Mundkur and Mr Azmatulla Khan of the Imperial Agricultural Research Institute, New Delhi, and from Mr E. W. Mason of the Imperial Mycological Institute, England; the author's thanks are due to them.

I. PHYCOMYCETES

Oomycetes

Peronospora Gaumannii Mundkur (*Sci. Monogr. Counc. Agri. Res., India,* **12**: 8, 1938).
On leaves of *Argemone mexicana* L. Karimganj, Sylhet. S. Chowdhury. 7-2-44. Herb. Plant Path. Lab. Sylhet. No. 46.

P. parasitica (Pers.) de Bary (*Sacc.* VII: 249; *Ann. Myc.* **5**: 512, 1907).
On leaves of *Raphanus sativus* L. Habiganj. S. Chowdhury. 14-2-44. Herb. Plant Path. Lab. Sylhet. No. 47.

P. variabilis Gaumann (*Sacc.* XXIV: 39; *Beitrage zur Kryptogamen flora der Schweiz.* **5**: 226,1923).
On leaves of *Chenopodium album* L. Rainagar, Sylhet. S. Chowdhury. 12-2-44. Herb. Plant Path. Lab. Sylhet. No. 48.

Pseudoperonospora cubensis (Berk. & Curt.) Rost. (*Sacc.* XVI: 520; *Ann. Myc.* **10**: 244, 1912; Butler-*Fungi and Disease in Plants.* 311, 1918).
On leaves of *Cucumis melo* L. Sylhet. S. Chowdhury. 21-2-44. Herb. Plant Path. Lab. Sylhet. No. 49.

Pythium aphanidermatum (Edson) Fitzpatrick (*Mem. Dep. Agri. India Bot. Ser.* **15**: 79-84, 1928; *Sacc.* XXIV: 1332).
On the stems of *Amaranthus gangeticus* L. and on the fruits of *Lagenaria vulgaris* Seringe, Sylhet. S. Chowdhury. 7-6-44 and 12-12-44. Herb. Plant Path. Lab. Sylhet. Nos. 50, 51.

Zygomycetes

Chounephora infundibulifera (Currey) Cunningham (*Trans. Linn. Soc.* II *Ser. Bot.* 1: 417, 1879; *Sacc.* IX: 339: *Ann. Royal Bot. Gard. Cal.* **6**: 163, 1895).
On flowers of *Hibiscus rosa-sinensis* L. Sylhet. S. Chowdhury. 12-1-44. Herb. Plant Path. Lab. Sylhet. No. 52.

Cunninghamella elegans Lender (Sacc. XXI: 828).
Isolated from different types of soil collected from different localities of Sylhet.

Mucor racemosus Fresenius (*Sacc.* VII: 192; *J. Indian Inst. Sci.* **11A**, 12: 141-60, 1928).
Isolated from arable soils of Maulvibazar and Karimganj.

Rhizopus nigricans Ehrenberg (*Sacc.* VII: 212; *J. Indian Inst. Sci.* **11A**, 12, 41-60, 1928).
Isolated from *pan* (*Piper betle L.*) *boroj* soils of Shaistaganj and Karimganj.

II. ASCOMYCETES

Hemiascomycetes

Protomycetes macrosporus Unger (*Sacc.* VII: 319: *Ann. Myc.* **9**: 372, 1911).
In living green parts of *Coriandrum sativum* L. Lakshmibasa, S. Chowdhury. 27-1-44. Herb. Plant Path. Lab. Sylhet. No. 53.

DISCOMYCETES

Sclerotinia sclerotiorum (Lib.) de Bary [*Mem. Dept. Agri. India. Bot.* Ser. **13**. 2. 39-46, 1924 : *Sacc.* XXII : 644 as *S. sclerotiorum* (Lib.) Sacc. and Trott.].

On *Brassica campestris* L. var *sarson* Prain ; Purangaon. S. Chowdhury. 10-3-44. Herb. Plant Path. Lab. Sylhet. No. 54.

PYRENOMYCETES

Asterina camelliae Syd. & Butler (*Ann. Myc.* **9** : 389, 1911 : *Sacc.* XXIV : 474 *Abhandl. k. k. Zool. Bot. Gesellsch. Wien.* **7**, 3, 83, 1913).

On leaves of *Thea sinensis* L. Baraura, Sylhet. S. Chowdhury. 7-11-44. Herb. Plant Path. Lab. Sylhet. No. 55.

Asterinella stuhlmanni (P. Henn.) Theiss (*Broteria Ser. Bot.* **10**. 120, 1912 ; *Sacc.* XVII : 881 ; *Ann. Myc.* 9 : 392, 1911 as *Asterina stuhlmanni* P. Henn.).

On the leaves of *Ananas comosus* (L.) Merr. Debpur. Sylhet. S. Chowdhury. 10-12-44. Herb. Plant Path. Lab. Sylhet. No. 56.

Balladyna butleri Syd. (*Ann. Myc.* **9** : 388, 1911 : *Sacc.* XXIV : 373).

On the culms of *Bambusa* sp. Lahkipur, Cachar. S. Chowdhury. 8-8-44. Herb. Plant Path. Lab. Sylhet. No. 57.

Capnodium citri Berk. & Desm. (*Indian J. agric. Sci.* **6** : 97, 1936 ; *Sacc.* I : 78).

On leaves and fruits of *Citrus* sp. Sylhet, Haflong. S. Chowdhury. 10-2-44. Herb. Plant Path. Lab. Sylhet. Nos. 58, 59.

C. eugeniarum Cke. (*Grev.* **8** : 96, 1880 ; *Sacc.* I : 78).

On leaves of *Eugenia jambos* L. Shillong. S. Chowdhury. 12-9-44. Herb. Plant Path. Lab. Sylhet. No. 60.

C. ramosus Cke. (*Grev.* **21** : 76, 1893 ; *Sacc.* XI : 271).

On leaves of *Mangifera indica* L. Illaspur. S. Chowdhury. 21-12-44. Herb. Plant Path. Lab. Sylhet. No. 61.

C. theae Boed (Boedijn : *Bull. Jard. Bot. Buitenzorg Ser.* III, 11 : 223, 1931).

On leaves of *Thea sinensis* L. Sridharpur. S. Chowdhury. 19-10-44. Herb. Plant Path. Lab. Sylhet. No. 62.

Ceratostomella paradoxa (de Seynes) Dade [*Trans. Brit. Mycol. Soc.* **13** : 191, 1928 ; *Sacc.* XXII 1341 as *Thielaviopsis paradoxa* (de Seynes) v Hoehn ; *Agri. Res. Inst. Pusa Bull.* **127**, 1922].

On stems of *Areca catechu* L. and on the leaves and fruits of *Ananas comosus* (L.) Merr. Sylhet. S. Chowdhury. 12-7-44. Herb. Plant Path. Lab. Sylhet and Herb. Crypt. Ind. Orient. New Delhi. Nos. 63, 64.

Dothidea azmati Chowdhury n. sp.

Spots on the leaves distinct, hypophyllous ; stroma erumpent, usually pulvinate, sub-orbicular, single or gregarious, smooth, black, partly sunk in the tissue of the leaf. Perithecia sunk in the stroma ; asci oblong 58-74 × 9-12 μ, soon disappearing. Spores elliptical to fusiform, sub-biseriate, uniseptate, straight or very slightly curved, slightly constricted at the septa, 17-24 × 4-7 μ, brown.

On the living leaves of *Setaria palmifolia* Stapf. causing distinct leaf spots on both surfaces of the leaf ; Haflong. 30 December, 1943. Collected by S. Chowdhury.

Type specimen deposited in the Herb. Crypt. Ind. Orient. New Delhi. No. 65.

Maculis in foliis, destinctis, hypophyllis, stromatibus erumentibus, generatim pulvinatibus, sub-orbicularibus, unicis vel gregariis, atris, nigris, parte, in folii histu mergatum. Peritheciis in stromum mergatis ; ascis oblongis, 58-74 × 9-12μ, mox disapparentes. Sporidiis ellipticis vel fusiformis, sub-districhis, uniseptatis, strictis vel subcurvatis, ad septa paulo constrictis, 17-24 × 4-7μ, brunneis.

In foliis viris *Setariae palmifoliae* Stapf. Haflong, 30-12-43. S. Chowdhury. No. 65. Typus in Herb. Crypt. Ind. Orient. New Delhi.

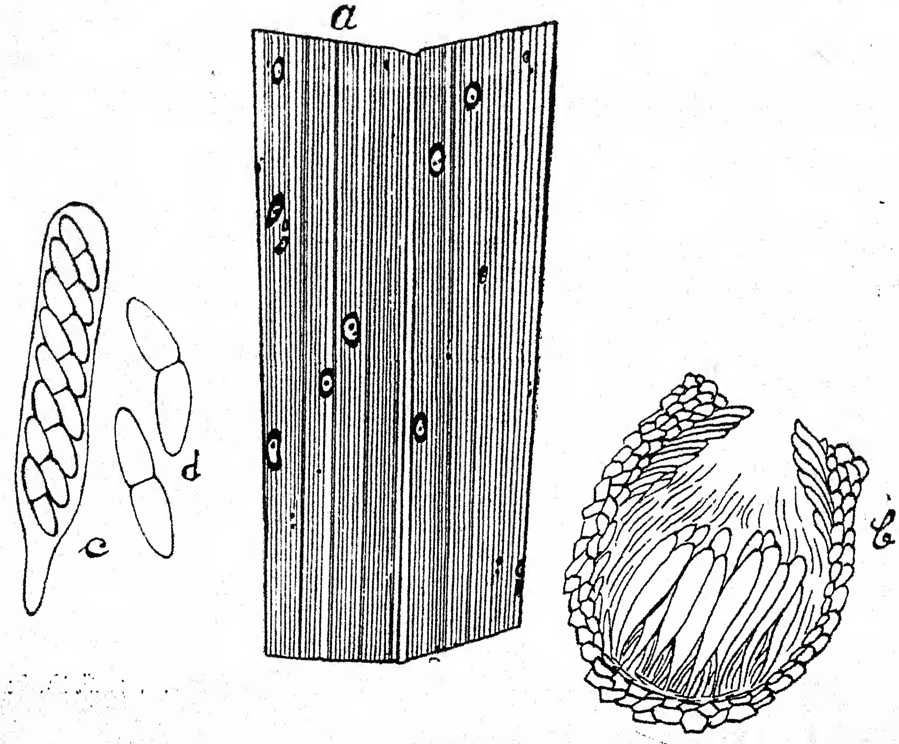

FIG. 1. *Dothidea Azmati* Chowdhury N. Sp.
a. Portion of a leaf showing spots. *b.* Section through a perithecium. *c.* An ascus with ascospores. *d.* Ascospores.

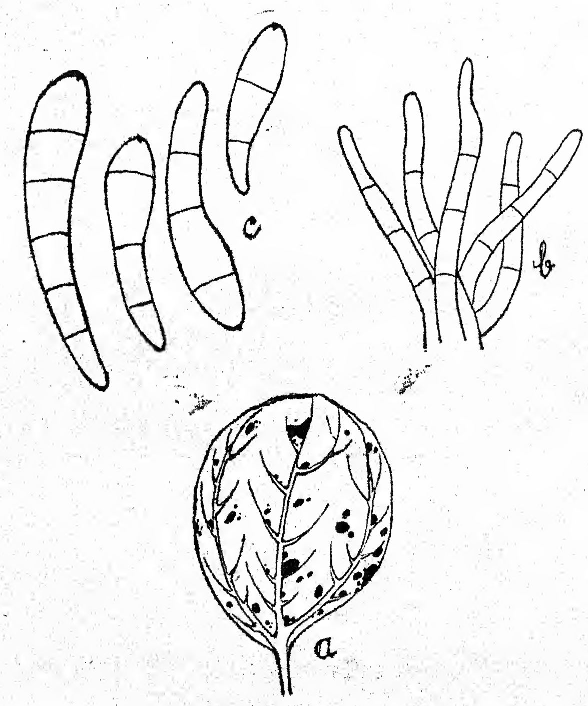

FIG. 2. *Cerospora Jujuabae* Chowdhury n. sp.
a. Leaf showing spots. *b.* A tuft of conidiophores. *c.* Conidia.

Glomerella cingulata (Stonem) Spaulding & v Schrenk (*Sacc.* XVII : 573 and XVI : 452 : *Ann. appl. Biol.* **6** : 245, 1920).
On leaves of *Piper betle* L. Jaintapur. S. Chowdhury. 15-9-44. Herb. Plant Path. Lab. Sylhet. No. 66.

G. major Tunst. (*Trans. Brit. Mycol. Soc.* **19** ; 331-36, 1935).
On woody branches of *Thea sinensis* L. Barkandi. S. Chowdhury. 17-7-44. Herb. Plant Path. Lab. Sylhet. No. 67.

Leptosphaeria agaves Syd. & Butler (*Ann. Myc.* **9** : 409, 1911 ; *Sacc.* XXIV : 979).
On fading leaves of *Agave sisalana* Perrine. Karimganj. S. Chowdhury. 7-7-44. Herb Plant Path. Lab. Sylhet. No. 68.

L. sacchari Breda de Haan (*Sacc.* XI : 324 ; *Ann. Myc.* **9** : 409 : 1911 ; *Mem. Dept. Agric. India Bot. Ser.* 1, 3 : 1-53, 1906).
On leaves of *Saccharum officinarum* L. Kamalganj. S. Chowdhury. 9-10-44. Herb. Plant Path. Sylhet No. 69.

Meliola butleri Syd. (*Ann. Myc.* **9** : 389, 1911 ; *Sacc.* XXIV : 338 ; *J. Dept. Sci. Cal. Univ.* V, 1-17, 1922).
On leaves of *Citrus* sp. Jaintapur. S. Chowdhury. 2-1-44. Herb. Plant Path. Lab. Sylhet. No. 70.

M. mangiferae Earl (*Sacc.* XXII : 48 ; *Ann. Myc.* **9** : 382, 1911).
On leaves of *Mangifera indica* L. Karimganj. S. Chowdhury. 18-11-43. Herb. Plant Path. Lab. Sylhet. No. 71.)

Nectria cinnabarina (Tode) Fr. (*Ann. Myc.* **9** : 393, 1911 ; *Sacc.* II : 479 ; *Quart. J. Indian Tea Assocn.* **3**, 86-91, 1923 ; *Quart. J. Indian Tea Assocn.* **1** : 32-44, 1925).
On stems of *Thea sinensis* L. Barkandi, Sylhet. S. Chowdhury. 8-8-44. Herb. Plant Path. Lab. Sylhet. No. 72.

Phyllachora bambusae Syd. & Butler (*Ann. Myc.* **13** : 441, 1915 : *Sacc.* XXIV : 576).
On living leaves of *Bambusa* sp. Sylhet. S. Chowdhury. 27-12-44. Herb. Plant Path. Lab. Sylhet and Herb Crypt. Ind. Orient. New Delhi. No. 73.

P. cynodontis (Sacc.) Niessl (*Ann. Myc.* **9**: 399, 1911 ; *Ann. Myc.* **11** : 328, 1913 ; *Sacc.* II : 602).
On leaves of *Cynodon dactylon*, Sylhet. S. Chowdhury. 18-2-43. Herb. Crypt. Ind. Orient., New Delhi and Herb. Plant Path. Lab. Sylhet. No. 74.

P. dalbergiae Niessl (*Hedw.* **20** : 99, 1881 ; *Sacc.* II, 594 ; *Ann. Myc.* **9** : 397, 1911).
On leaves of *Dalbergia sissoo* Roxb. Satgaon. S. Chowdhury. 8-3-44. Herb. Crypt. Ind. Orient. New Delhi and Herb. Plant Path. Lab. Sylhet. No. 75.

P. fimbristylicola Speg. (*Ann. Myc.* **9** : 398, 1911 ; *Sacc.* XXII, 423).
On leaves of *Fimbristylis* sp. Habiganj. S. Chowdhury. 12-10-43. Herb. Plant Path. Lab. Sylhet. No. 76.

P. sorghi v Hoehn (*Sacc.* XXII : 426).
On leaves of *Sorghum vulgare* Pers. Katakhal. S. Chowdhury. 21-9-43. Herb. Plant Path. Lab. Sylhet. No. 77.

III. BASIDIOMYCETES

Ustilaginales

Sphacelotheca sorghi (Lk.) Clinton (*Sacc.* VII : 456 as *Ustilao sorghi* (Link) Pass., *Ann. Myc.* **4** : 425, 427, 1906 ; *Agri. J. India* **17** : 159-62 1922 ; *Mycologia* **22** : 125-58, 1930).
On the ovaries of *Sorghum halepense* (L.) Pers. (Syn. *Andropogon halepensis* Brot.) Sylhet. S. Chowdhury. 6-2-43. Herb. Crypt. Ind. Orient., New Delhi., and Herb. Plant Path. Lab. Sylhet. No. 78.

UREDINALES

Hemileia vastatrix Berk. & Broome (*Sacc.* VII : 585 ; *Zeitsch. fur Pflanzenkr.* **15** : 47, 1905 ; *Popular Sci. Rev.* **15** : 161-68, 1875 ; *Planters' Chron.* **19** : 698, 1924 ; *Grev.* **4** : 116, 1875 ; *Kew Bull.* 1906 : 35-42, 1906).

On leaves of *Coffea arabica* L. Dalaipara, Sylhet. S. Chowdhury. 2-8-44. Herb. Plant Path. Lab. Sylhet. No. 79.

Puccinia maydis Bereng (*Sacc.* VII : 659 as *P. sorghi* Schw. ; *Ann. Myc.* **4** : 434, 1906 : *J. Asiat. Soc. Bengal* **60** : 214, 1891 as *P. sorghi* Schw. Butler—*Fungi and Disease in Plants*, 193, 1918).

On leaves of *Zea mays* L. Upper Shillong. S. Chowdhury. 6-8-44. Herb. Plant Path. Lab. Sylhet, and Herb. Crypt. Ind. Orient. New Delhi. No. 80.

P. nakanishikii Diet (*Ann. Myc.* **4** : 435, 1906 ; *Sacc.* XXI : 691).

On leaves of *Cymbopogon khasianus* Stapf. ex Bor. Latu, Sylhet. S. Chowdhury. 12-12-43. Herb. Plant Path. Lab. Sylhet, and Herb. Crypt. Ind. Orient., New Delhi. No. 81.

P. thwaitesii Berk (*Ann. Mycol.* **4** : 431, 1906 ; *Sacc.* VII : 720).

On leaves of *Justicia gendarussa* L. Sylhet. S. Chowdhury. 8-8-44. Herb. Plant Path. Lab., Sylhet, and Herb. Crypt. Ind. Orient. New Delhi. No. 82.

Uromyces fabae (Pers) de Bary (*Sacc.* VII : 531 ; *Ann. Myc.* **4** : 428, 1906 ; *Ann. Myc.* **10** : 255, 1912).

On leaves, stems and pods of *Lens esculenta* Moench. Kasba, Sylhet. S. Chowdhury. 6-12-44. Herb. Plant Path. Lab. Sylhet. No. 83.

HYMENOMYCETES

Agaricus latipes Berk (Sacc. V : 1000).

On the ground, Dawki. S. Chowdhury. 18-8-44. Herb. Plant Path. Lab. Sylhet. No. 84.

Boletus areolatus Berk (*Sacc.* VI : 44).

In open pastures. Upper Shillong. S. Chowdhury. 28-8-44. Herb. Plant Path. Lab. Sylhet. No. 85.

B. flavipes Berk (*Sacc.* VI : 28).

On the ground Upper Shillong. S. Chowdhury. 28-8-44. Herb. Plant Path. Lab. Sylhet. No. 86.

B. scrobiculatus Berk. (Sacc. VI : 37).

On soil in open places, Moflong, Khasi Hills. S. Chowdhury. 29-8-44. Herb. Plant Path. Lab. Sylhet. No. 87.

Exobasidium vexans Massee (*Kew Bull.* 1898 : 105-12, 1898 ; *Sacc.* XVI : 198 ; Butler : *Fungi and Disease in Plants*, 422, 1918. *Indian Tea Assocn. Bull.* **3**, 1906 : *Agri Res. Inst. Pusa Bull.* **18**, 1910 ; *Agri. J. India* **5** : 126-37, 1910 ; *Ann. Myc.* **10** : 274, 1912 ; *Quart. J. Indian Tea Assocn.* 1 : 35-43, 1922 ; *Quart. J. Indian Tea Assocn.* **1** : 20-4, 1927).

On leaves and twigs of *Thea sinensis* L. Sylhet. S. Chowdhury. 7-9-43. Herb. Plant Path. Lab. Sylhet. No. 88.

Polyporus anthelminticus Berk. (*Gard. Chron.* 753, 1866 ; *Sacc.* VI : 79 ; *Proc. Sci. Convention, Indian Assoc. Cult. Sci. for the year* 1920-21 : 30, 1923).

On dead root of *Bambusa sp.* Inathganj, Sylhet. S. Chowdhury. 2-8-45. Herb. Plant Path. Lab. Sylhet. No. 89.

P. friabilis Bose (*J. Indian Bot.* **2** : 300-1, 1921).

On the ground and on the living and dead *Bambusa* sp. Lakshmibasa, Sylhet. S. Chowdhury. 16-7-44. Herb. Plant Path. Lab. Sylhet. No. 90.

Poria diversispora Berk. & Broome (Sacc. VI : 324 ; *Bull. Charmichael Med. Coll.* **1** : 1, 1920).

Common usually on old *Bambusa* sp. Sylhet. S. Chowdhury. 10-2-44. Herb. Plant Path. Lab. Sylhet. No. 91.

P. hypobrunnea Petch. (*Ann. Royal Bot. Gardn. Peradeniya* **6** : 51, 1916 ; *Sacc.* XXIII : 419 ; *Quart. J. Indian Tea Assocn.* **1** : 38, 1925).

A common cause of die-back of the stems of *Thea sinensis* L. Binnakandi, Cachar. S. Chowdhury. 14-3-43. Herb. Plant Path. Lab. Sylhet. No. 92.

Stereum percome B. & Br. (*Sacc.* VI : 576 ; *Ann. Myc.* **34** : 38, 1936).
On living and dead *Bambusa* sp. Silchar, Cachar. S. Chowdhury. 17-3-43. Herb. Plant Path. Lab. Sylhet. No. 93.

S. petaloides Berk. (*Sacc.* VI : 557 ; *Ann. Myc.* **34** : 27, 1936).
On dead *Bambusa* sp. Karimganj, Sylhet. S. Chowdhury. 12-3-43. Herb. Plant Path. Lab. Sylhet. No. 94.

Trametes cubensis (Mont.) Sacc. (*Sacc.* IX : 198 ; *Ann. Myc.* **35** : 134, 1937).
On dead *Bambusa* sp. Matijuri, Hailakandi. S. Chowdhury. 8-3-44. Herb. Plant Path. Lab. Sylhet. No. 95.

T. mollis Fries (*Sacc.* VI : 354 ; *J. Dept. Sci. Calcutta Univ.* **11** : 11, 1934).
On branches of *Alnus* sp. Shillong. S. Chowdhury. 24-10-44. Herb. Plant Path. Lab. Sylhet. No. 96.

T. persooni Fries (*Sacc.* VI : 272 as *Polystictus persooni*. *Ann. Myc.* **35** : 133, 1937).
On living and dead *Bambusa* sp. Katakhal, Cachar. S. Chowdhury. 19-3-43. Herb. Plant Path. Lab. Sylhet. No. 97.

IV. FUNGI IMPERFECTI

Hyphomycetes

Acrothecium lunatum Wakker (*Sacc.* XIV : 1089 ; *Mem. Dept. Agri. India. Bot. Ser.* **11**, 3, 57-74, 1921 ; *Annotated Account of Fungi Received at the Imperial Bureau of Mycology.* List II : 2, 1928).
On leaves of *Andropogon sorghum* Brot. Sylhet. S. Chowdhury. 15-7-44. Herb. Plant Path. Lab. Sylhet. No. 98.

Cephalosporium sacchari Butler (*Mem. Dept. Agri. India. Bot. Ser.* **6**, 6 : 181, 1913 : Butler : *Fungi and Disease in Plants* : 402 : 1918).
In culms of *Saccharum officinarum* L. Sylhet. S. Chowdhury. 17-11-44. Herb. Plant Path. Lab. Sylhet. No. 99.

Cercospora arachidiocola Hori (*Phytopath.* **23** : 627-640, 1933 ; Uppal *et al* : The Fungi of Bombay. 29, 1935).
On leaves, stems and petioles of *Arachis hypogaea* L. Haflong. S. Chowdhury. 6-8-43. Herb. Plant Path. Lab. Sylhet. No. 100.

C. dioscoreae Ell. & Mart. (*Sacc.* IV : 479 ; *Annales Crypt. Exot.* II : 265, 1929, 1930).
On leaves of *Dioscorea* sp. Satgaon. S. Chowdhury. 15-1-43. Herb. Plant Path. Lab. Sylhet. No. 101.

C. jujubae Chowdhury n. sp.
Mycelium hypophyllous, branched, septate, both internal and external. Conidiophores fasciculate, emerging through the stomata or rupturing the epidermis, fuscous, 48-152×4-7 μ, 1-4 septate, constricted at the septa, sometimes swollen at the base, with distinct geniculations and conidial scars. Conidia clavate, solitary, apical, straight or very slightly curved, light olive gray, 1-5 septate, 25-45×8-10 μ, bearing a distinct hilum at the base.
On the lower side of the leaves of *Zizyphus jujuba* Lam. Maulvibazar. 8-2.44. Collected by S. Chowdhury.
Type specimen deposited in the Herb. Crypt. Ind. Orient. New Delhi.
Mycelie hypophyllo, ramoso, septate, interne et externe ; conidiophoris fasciculatis, ex stomatibus emergentis vel epidermis erumpentis, fuscis, 48-152×4-7 μ, 1-4 septatis, ad septa constrictis ad bascim interdum, ampulliformism cum distinctis geniculatimibus et conidiolibus hilibus. Conidiis clavatis, solitariis, apicis, strictis vel subcurvatis, pallide olivaceis, 1-5 septatis, 25-45×8-10 μ, ad bsaim cum hilo distincto.
In foliis *Ziziphi jujubi* Lam. Maulvibazar. 8-2-44. (S. Chowdhury No. 102 Typus). Typus in Herb. Crypt. Ind. Orient., New Delhi.

C. longipes Butler [*Mem. Dept. Agri. India. Bot. Ser.* **1**, 3, 41, 1906 ; *Annales Crypt. Exot.* II, 267, 1929 (1930) ; Butler : *Fungi and Disease* in Plants. 405, 1918].
On leaves of *Saccharum officinarum* L. Sylhet. S. Chowdhury. 7-11-44. Herb. Plant Path. Lab. Sylhet. No. 103.

C. musarum Zimm. (*Central Bakt., Abt.* ii, 8, 219. 1902 ; *Kew Bull. Misc. Inf.* 1914, 159).
On leaves of *Musa sapientum* L. Sylhet. S. Chowdhury. 7-3-44. Herb. Plant Path. Lab. Sylhet and *Herb. Crypt. Ind. Orient.* New Delhi. No. 104.

C. nicotianae Ell. & Ev. [*Sacc.* XI : 628 ; Butler : *Fungi and Disease in Plants* : 344, 1918 ; *Annales Crypt. Exot.* II : 267, 1929 (1930)].
On leaves of *Nicotiana tabacum* L. Sylhet. S. Chowdhury. 3-3-44. Herb. Plant Path. Lab. Sylhet and Herb. Crypt. Ind. Orient. New Delhi. No. 105.

C. pisi-sativae Stevenson [*Sci. Monogr. Imp. Counc. agri. Res.* India. **12** ; 32, 1938. *Ann. Rept. Insular Exp. Sta. Porto Rico* (1917-18) 138, 1919].
On leaves of *Pisum sativum* Sylhet. S. Chowdhury. 5-3-44. Herb. Plant Path. Lab. Sylhet. No. 106.

C. ricinella Sacc. & Berk. (*Sci. Monogr. Imp. Counc. agri. Res. India* **12**, 32, 1938).
On leaves of *Ricinus communis* L. Sylhet. S. Chowdhury. 14-2-44. Herb. Plant Path. Lab. Sylhet and Herb. Crypt. Ind. Orient. New Delhi. No. 107.

C. solanacea Sacc. [*Sacc.* IV : 449 ; *Annales Crypt. Exot.* II : 269, 1929 (1930)].
On leaves of *Solanum melongena* L. S. Chowdhury. 12-3-44. Herb. Plant Path. Lab. Sylhet and Herb. Crypt. Ind. Orient. New Delhi. No. 108.

C. sorghi Ell. & Ev. (*Sacc.* X : 656 ; Ill. *Biol. Monographs* **12** : 57, 1929 ; *Mem. Dept. Agri. India Bot. Ser.* **18** : 259-279, 1931).
On leaves of *Andropogon sorghum* Brot. Sylhet. S. Chowdhury. 10-7-44. Herb. Plant Path. Lab. Sylhet. No. 109.

C. theae Breda de Haan (*Sacc.* XVIII : 598 ; *Zeitsch fur Pflaenzenkr.* **15** : 47, 1905 ; Butler : *Fungi and Disease in Plants*, 446, 1918 ; *Quart. J. Indian Tea Assocn.* 1927, **2** : 73-86 ; **4** : 173-182, 1927).
On the leaves of *Thea sinensis* L. Sylhet. S. Chowdhury. 21-7-44. Herb. Plant Path. Lab. Sylhet. No. 110.

Cerebella inquinans (Berk. & Broome) Petch (*J. Proc. Asiat. Soc. Beng.* N.S. **17** : 207, 1921 ; *Sacc.* IX : 20, 1891 ; *Phytopath.* **32** : 613, 1942).
On *Digitaria Royleana* Prain. Rainagar, Sylhet. S. Chowdhury. 17-9-44. Herb. Plant Path. Lab. Sylhet. No. 111.

Helminthosporium frumantacei Mitra (*Trans. Brit. Mycol. Soc.* **15** : 286, 1931).
On leaves of *Panicum frumantaceum* Roxb. Habiganj. S. Chowdhury. 18-3-44. Herb. Plant Path. Lab. Sylhet. No. 112.

H. gramineum Rabenh (*Sacc.* X : 615 ; *Zeitsch. fur Pflanzenkr.* **15** : 46, 1905 ; Butler : *Fungi and Disease in Plants*, 186, 1918).
On leaves of *Hordeum vulgare* L. Samshernagar. S. Chowdhury. 12-2-44. Herb. Plant Path. Lab. Sylhet. No. 113.

H. nodulosum Berk. & Curt. (*Sacc.* IV : 421 ; Butler. *Fungi and Disease in Plants*. 341, 1918 ; *Indian J. agric. Sci.* **4** : 943-73, 1934).
On leaves, stems and inflorescences of *Eleusine corocana* Gaertn. Upper Shillong. S. Chowdhury. 14-9-44. Herb. Plant Path. Lab. Sylhet. No. 114.

H. sacchari Butler (*Mem. Dept. Agri. India. Bot. Ser.* **6** : 204, 1913 ; Butler : *Fungi and Disease in Plants* : 407-8, 1918).
On leaves and midribs of *Saccharum officinarum* L. Kamalganj. S. Chowdhury. 15-12-44. Herb. Plant Path. Lab. Sylhet. No. 115.

H. torulosum (Syd.) Ashby (*Bull. Dep. Agri. Jamaica.* s. 2, ii, 95-128, 1913 ; *Phytopath.* **18** : 531-8, 1928 ; *Internat. Bull. Plant Protect.* IV, 7, 103-4, 1930 ; *Trop. Agriculture* **11** : 6, 1934).
On leaves and fruits of *Musa sapientum* L. Karimganj. S. Chowdhury. 19-10-43. Herb. Plant Path. Lab. Sylhet. No. 116.

H. tritici-repentis Diedicke (*Sacc.* XXII : 1393 ; *Indian J. agric. Sci.* **4** : 692-700, 1934).
On leaves of *Triticum vulgare* Host. Samshernagar. S. Chowdhury. 12-2-44. Herb. Plant Path. Lab. Sylhet. No. 117.

H. turcicum Passerini (*Sacc.* IV : 420 ; *Mem. Dept. Agri. India. Bot. Ser.* II : 219-2, 1923).
On leaves and inflorescences of *Zea mays* L. Shillong. S. Chowdhury. 20-8-44. Herb. Plant Path. Lab. Sylhet. No. 118.

Sphaeropsidales and Melanconiales

Botryodiplodia theobromae Patouill (*Sci. Monogr. Imp. Counc. Agri. Res. India.* **1** : 152, 1931).
On roots of *Thea sinensis* L. Barkandi, Sylhet. S. Chowdhury. 15-9-44. Herb. Plant Path. Lab. Sylhet. No. 119.

Colletorichum catechu Diedicke (*Ann. Myc.* **14** : 219, 1916).
On leaves of *Areca catechu* L. Sylhet. S. Chowdhury. 15-7-43. Herb. Plant Path. Lab. Sylhet. No. 120.

C. papayae (P. Henn.) P. Henn. (*Sci. Monogr. Imp. Counc. Agri. Res. India* **12** : 38, 1938).
On dead petioles of *Carica papaya* L. Haflong. S. Chowdhury. 12-11-44. Plant Path. Lab. Sylhet. No. 121.

Diplodia calami Niessl. (*Hedw.* **17** : 176, 1878 ; *Sacc.* III : 372 ; *Ann. Myc.* **14** : 200, 1916).
On leaves of *Calamus* sp. Inathganj, Sylhet. S. Chowdhury. 12-1-44. Herb. Plant Path. Lab. Sylhet. No. 122.

Hendersonia theicola Cke. (*Grev.* **1** : 90, 1872 as *H. theaecola* ; *Sacc.* III : 427).
On leaves of *Thea sinensis* L. Binnakandi, Cachar. S. Chowdhury. 11-3-43. Herb. Plant Path. Lab. Sylhet. No. 123.

Pestalotia palmarum Cke. (*Grev.* **4** : 115, 1876 ; *Sacc.* III : 796 ; *Agri. Res. Inst. Pusa Bull.* **9** : 21, 1908 ; *Agri. Res. Inst. Pusa Bull.* **195**, 1929 ; *Mycologia* **34** : 308-17, 1942).
On leaves of *Borassus flabellifer* L. Sylhet. S. Chowdhury. 14-12-43. Herb. Plant Path. Lab. Sylhet and Herb Crypt. Ind. Orient., New Delhi. No. 124.

P. theae Sawada (Butler : *Fungi and Disease in Plants.* 451, 1918 *Quart. J. Indian Tea Assocn.* **1** : 37-43, 1920).
On leaves of *Thea sinensis* L. Jallalnagar. Sylhet. S. Chowdhury. 18-9-44. Plant Path. Lab. Sylhet and Herb. Crypt. Ind. Orient., New Delhi. No. 125.

Phyllosticta sulata Chowdhury (*Indian J. agric. Sci.* **14** : 395-8, 1944).
On leaves of *Carica papaya* L. Sylhet. 21-11-44. S. Chowdhury. Plant Path. Lab. Sylhet and Herb Crypt. Ind Orient., New Delhi. No. 126.

Septoria cannabis (Lasch) Sacc. (*Sacc.* III : 557 ; *Ann. Myc.* **14** : 213, 1916).
On leaves of *Cannabis sativus* L. Shillong. S. Chowdhury. 18-8-44. Herb. Plant Path. Lab. Sylhet. No. 127.

REVIEW

A Review of the Literature on Soil Insceticides. Edited by H. C. Gough (*Published by the Director, Imperial Institute of Entomology, London, p. 161, Price 10s.*).

THE application of an insecticide to the soil is much more complex than applying it to plant foliage, etc., because in the soil the insecticide is likely to disturb the equilibrium in soil micro-organisms or may react directly or indirectly with manures and fertilizers. There are numerous observations in literature of various countries on the efficacy of soil insecticides. Dr. Gough has rendered a great service to the entomologists by compiling all the information available in the brochure under review. His method of treatment of the subject is admirable. He has discussed all the important insecticides one by one and under each individual insect against which they have been applied they are arranged in a systematic manner. The important group of soil nematodes is omitted deliberately because this subject is recognized by the author to have a literature of its own. The control of Myriopods and Arachnide is, however, included.

When the brochure appeared it was thought that some conclusions would be drawn as to which insecticides are most efficacious against various important pests. However, the conclusions actually drawn from the review by Dr. Gough are rather meagre not because he has not examined the various research papers critically but because of the fact that contradictory results have been obtained by different authors for almost all the substances tested. This shows that no systematic attempt has yet been made to critically examine the effect of different insecticides by isolating their influence from the other factors which operate in the soil medium. This also emphasizes the complexity of the problem as stated above. Anyway Dr. Gough's work is likely to result in simplification of the problem by stimulating research work in an extensive and critical manner.—H. S. P.

PLANT QUARANTINE NOTIFICATIONS

Notification No. F. 15-1/45-A., dated the 27th December 1945, of the Government of India in the Department of Agriculture.

The notifications of the Government of India in the Department of Agriculture No. F. 15-1/45-A, dated the 25th September 1945 and the 12th November 1945 are hereby cancelled.

Notification No. F. 3-1/46-PP., dated the 17th August 1946, of the Government of India in the Department of Agriculture.

In exercise of the powers conferred by Sub-section (1) of Section 3 of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to direct that the following further amendment shall be made in the Order published with the notification of the Government of India in the late Department of Education, Health and Lands No. F. 320/35-A., dated the 20th July 1936, namely: —

In paragraph 8B of the said Order, after the word " Burma " the words " or the Kalat State " shall be inserted.

MGIPC—M—III-1-14—24-9-47— 600.